Electrical Engineering

February
1939

Published Monthly by the
American Institute of Electrical Engineers

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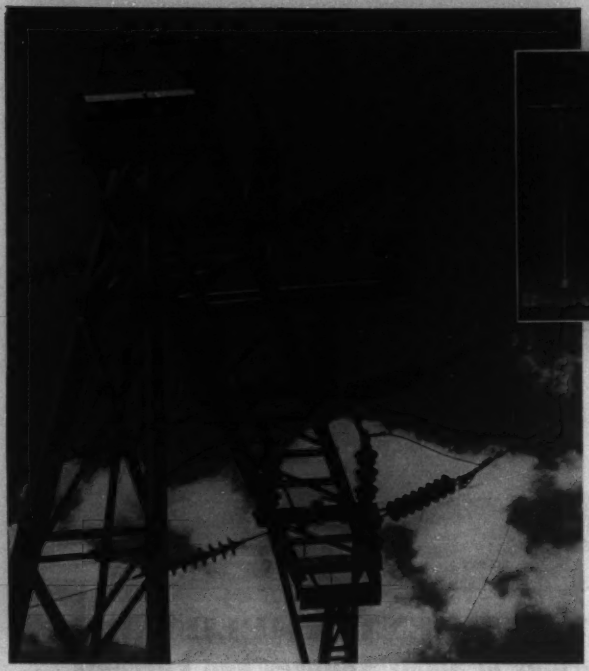

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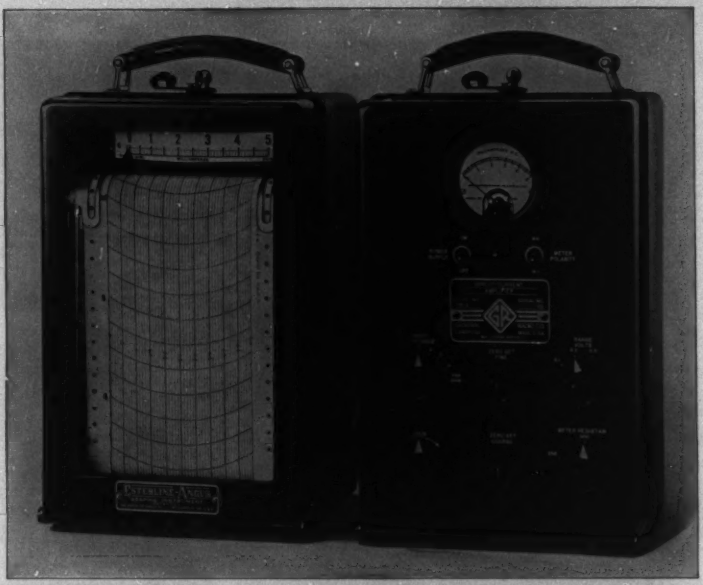

NEW DIRECT-CURRENT AMPLIFIER

for Continuous Recording of Small Voltages and Currents

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The amplifier and recorder constitute a calibrated recording voltmeter. With known input resistances, a milliammeter or microammeter for recording d-c voltage and current variations can be obtained directly.

The new amplifier can be used in automatic control circuits where the amplifier output operates relays to control the original device which drives the amplifier.

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Cambridge, Massachusetts

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Electrical Engineering

Registered U. S. Patent Office

for February 1939—

The Cover: Electrical insulation continues its advance through fundamental research. This month's cover shows a microscopic view in polarized light of a mixture composed of ceryl alcohol and liquid paraffin; as this mixture was cooled, the power factor increased markedly at temperatures near which the butterfly-like patterns began to form.

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¶ Correspondence is invited on all controversial matters.

High Lights

Mathematics, Physics, and Electrical Engineering. Early departments of electrical engineering were outgrowths of physics departments in American universities; the two again are becoming more closely allied as research in fundamental physical phenomena develops advances in engineering (*Transactions pages 35–6*). Co-ordination between mathematics, physics, and electrical-engineering subjects must exist to some degree in every electrical-engineering curriculum; it may be achieved in part through informal and voluntary discussions between instructors. Representative committees may guide such revisions as are made necessary by new advances (*Transactions pages 36–7*). Educators disagree on the real causes of the lack of co-ordination of instruction in mathematics, physics, and electrical engineering; an examination of some of those more commonly advanced leads to a proposed evolutionary process which might improve the present faculties in large universities (*Transactions pages 38–40*). Facility in the use of mathematics and physics in the solution of engineering problems is developed in a plan of study in which typical problems of practical value are assigned. Problems are selected from those described in technical publications; references to the published papers are given after the students have completed their solutions (*Transactions pages 40–1*). A broad philosophy and viewpoint with respect to science that are difficult to develop in engineering courses may be developed by proper teaching of the co-ordinated work (*Transactions pages 42–3*).

Polarity Limits of the Sphere Gap. Extensive use of sphere gaps in high-voltage tests and research necessitates complete data on their characteristics and limitations. It is reported that 60-cycle polarity characteristics of grounded sphere gaps correlate sufficiently well with the positive and negative impulse calibration curves to permit the use of the former for determining the polarity limits for sphere gaps (*Transactions pages 56–9*).

Management and Society. "Management must stand by its colors, struggling to maintain the cause of free enterprise in a world threatened with too much regimentation," said the chairman of the board of a leading electrical manufacturing company who added that "free enterprise may confidently hold up its head as representative of one of the most vital functions in our national economy today" (*pages 81–5*).

Self-Excitation of Induction Motors. It has been known for some time that an induction motor may supply power as a generator when provided with excitation from capacitors. The increasing use of capacitors for power-factor correction has increased the importance of predetermining the characteristics of an induction machine when operating under these conditions (*Transactions pages 47–51*).

International Units. New absolute units for electrical quantities will be placed in effect in 1940 as another step in the development of international standards. The change will be insignificant from the standpoint of ordinary electrotechnics but will need to be taken into account in electrophysics (*pages 78–80*).

Opportunities in Manufacturing. Electrical manufacturing is one of the industries in which engineers are a relatively large percentage of the employees. Some 1,600 companies of various sizes in the United States offer opportunities in research, development, design, application, and sales (*pages 72–7*).

Automatic Telephone Devices. A voltage range of about 70 decibels (over 3,000 to 1) must be considered for telephonic message circuits. In order to accommodate such ranges of intensity to certain transmission media, such as radio links, a new family of automatic devices has been developed (*Transactions pages 62–7*).

Lightning Arresters. To meet a need for information dealing with the testing and application of lightning arresters, the lightning subcommittee of the AIEE committee on protective devices has prepared a report outlining current practices covering line-type arresters rated at 15 kv or less (*Transactions pages 68–71*).

Edison Medalist. Accomplishments of the recipient of the 1938 Edison Medal in engineering and in education are revealed by one of his former students in an address delivered during the 1939 AIEE winter convention (*pages 64–6*).

Incentive and Security. For continued achievement in civilization, proper balance must be maintained between incentive for further progress and security of social position. Without incentive there can be no long-time security (*pages 67–71*).

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Social Significance. Engineering's social significance lies much deeper than the physical manifestations that are evident today. Civilization and community life have developed with engineering progress, and study of the relation of engineering and political economy is now a real need (*pages 59–63*).

Trends in Hydroelectric Plants. Recent trends in the design and arrangement of electrical equipment in hydroelectric generating stations have been in the general direction of greater simplification, reliability, and lower first cost (*Transactions pages 78–82*).

Deceleration Tests. By proper selection of equipment and analysis, deceleration test methods, which in the past have been limited mostly to large machines, may be applied to smaller machines having relatively short stopping periods (*Transactions pages 72–6*).

Variable-Register-Ratio Meter. To investigate the possibility of applying the law of supply and demand to the metering of electric energy, an experimental meter having a register ratio variable in accordance with the system demand has been devised (*Transactions pages 76–8*).

Bismuth-Bridge Fluxmeter. By making suitable alterations, a bismuth-bridge magnetic fluxmeter designed originally for measuring d-c fields can be adapted for the measurement of a-c fields and for transient-flux investigations as well (*Transactions pages 52–5*).

New Trim Size. Effective with the January issue, the trim size of ELECTRICAL ENGINEERING has been changed to $8^3/_4$ by $11^1/_8$ inches simultaneously with other technical journals, in order to accommodate advertising plates of a "standard" size interchangeably.

Coming Soon. Among special articles and technical papers undergoing preparation for early publication are: an article discussing the benefits of graduate training for engineers by L. W. W. Morrow (F'25); an article outlining the power requirements for electrochemical, electrometallurgical, and allied industries; a paper by J. M. Gaylord (F'35) on the pumping system of the Colorado River aqueduct; a paper by E. W. Morris (M'35) on applications of copper-oxide rectifiers; a paper by William T. Thomson (A'37) on ferroresonant circuits; a paper by H. H. Skilling (M'34) on the electric strength of air at high pressure; a paper by A. M. Skellett on a narrow-band transmission system for animated line images; a paper by R. E. Pierce (M'31) and B. W. Hamilton on phase-angle control of system interconnections; and a paper by J. A. M. Lyon (A'38) on the electrostatic unbalance of transmission lines and its effect on Petersen coils.

Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the fifteenth of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London).

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The Social Significance of Engineering

By DUGALD C. JACKSON
FELLOW AIEE

Civilization grows as a consequence of community contacts among human beings, which contacts are largely made possible by engineering. The relation of engineering to society and social adjustment is one of inseparability, and although much progress has been made through historic time in the improvement of living conditions, further opportunities for improvement are outlined in this article by a noted engineer.

BECAUSE the effects of engineering run all through living conditions, engineering's part in the development of civilization is of great importance to engineers and to engineering education. The subject discussed here is a broad and pervasive one which means the import of engineering to society. It also includes various subtopics by implication. For example, it includes the social influence of engineering, which means the effect through the senses which engineering exerts on society; it includes the social implications of engineering, which means the intimate connections which relate engineering to social organization and social interrelations; and it also includes, among other things, the status or position of engineering as an entity with respect to society organization as an entity. In this discussion I will go somewhat broadly into social relations and deal with the tripartite interrelations of engineering, social organization, and civilization.

It is proper here to comment that true civilization grows as a consequence of community contacts among human beings, and intimate community contacts, broadly speaking, are made possible by and are dependent on the fruits of engineering. Such fruits became vaguely manifest many thousands of years ago and have steadily ripened and increased in scope and variety, through those thousands of years, down to the present time. Further ripening and variety-increases apparently will go on through future ages. I cannot here go into the demonstration of the fundamental and continuous relations existing between social organizations and engineering. Those who may be interested to trace the growth of these influences are referred to a series of six articles on "Engineering's Part in the Development of Civilization" published in *Mechanical Engineering* from July 1938 to December 1938. In those articles I have shown that community life was made possible by engineering; that some degree of civilization (which rests on principles of ethics and codes of morals) is a necessary accompaniment of community life; and, as a consequence, engineering is an inseparable companion of civilization. The increased responsibility for mutual sympathy and mutual welfare laid on individuals and on communities by the doctrines of the Christian religion have increased for engineering its opportunities to serve and its responsibilities.

The mental picture of the outcome of engineering usually held by human beings in the civilized world is of steam engines and what they have done for us; steam railroads; steamships; electric telegraphs; telephones; automobiles and hard-surfaced roads; radio sets and broadcasting stations; great structures like tall buildings, bridges, canals, harbors, and irrigation works; potable water supplies and sewerage; manufacturing plants; manufactured products; and like physical evidences. But these are only emblems, which are at the surface today. These are instrumentalities of engineering which have social significance, but it is inadequate, even superficial, to rest our attention with them.

To understand truly the social significance of engineering and the part that engineering has played in the development of civilization we must go deeper into the problems of society and the molding influences of engineering thereon. It is necessary to begin with the conditions of the earliest village life, which originated in prehistoric times but which have left their records in the development of community life and civilization. We can picture these conditions from artifacts and other remains that have come down to us. It was through village life that civilization began, and through engineering that village life became possible. The single family or small group, living in a more or less roaming and precarious stage, had no civilization; but village life led to community of interests from which sprang the development of ethical principles and codes of morals that are the basis of civilization. It was thus that civilization germinated out of social organization.

Having germinated, it expanded over the world along with the movements of peoples, as sailing and rowing ships and maritime commerce grew up, and as extending trails and roads made some land commerce possible. Man seems to have been a natural trader in commerce after his gregarious period had arrived. The foundation development required a growing state of material and social well-being among men, with which there became associated a sympathetic mutual interest between individuals, and by individuals for the community welfare, in villages. It is the community of interests which arises from integration of groups of people, that develops the qualities which characterize civilization; and conditions for living which make decent village life possible depend on engineering.

Principal part of text of an address delivered at a conference on the social significance of engineering at Lehigh University, Bethlehem, Pa., October 26, 1938.

DUGALD C. JACKSON is professor emeritus of electrical engineering, Massachusetts Institute of Technology, Cambridge. A biographical sketch of Doctor Jackson may be found in the January 1939 issue, page 50; a review of his accomplishments appears on pages 64–6 of this issue.

Conscience and morals arise out of the social contacts in the family, clan, and community, and civilization germinated in the community. Thus engineering was a frontier influence on civilization and social relations and it has been expanding that influence ever since.

The influences of metallurgy, of other engineering inventions, of agriculture, of domestication of animals, and of written language became of great force among the early peoples; and community concentration became greater. Aided by engineering factors, trade between communities grew up and caused further extension of human contacts which depend for their amity on ethics and morals. Tools and simple weapons are evidences of artisanship as also are crude pottery, weaving, simple agriculture, and some domestication of animals. But the trail of rudimentary structures, foresighted judgment regarding desirable village locations, and planned metallurgy, which trail was already trodden by some communities at the Dawn of History, is the pathway of engineering—that is, it is the trail of the use of intellectual processes to bring together and combine physical elements into a co-ordinated unity (such as a structure or process) for the convenience of man.

Add complex machines to these other engineering features, as is ultimately done in engineering, and we step far along in the possibilities for social relations. At the Dawn of History man had come to the stage when security of life and livelihood could be sought after with some expectation of success. Each step forward in the progress of engineering invention which contributed to the security of life and property for early men gave further impetus to the tendency toward community living and this led to further emphasis also on ethical relations between man and man and tribe and tribe. In this connection the importance of the ethical relations is to be remembered. Power to control men's life and property without restraint gives power to control their subsistence and this is equivalent to power over their will. Out of this condition most of the autocrats and dictators of the world have made their hold secure. Let us beware!

Group Association

Civilization connotes harmonious co-operation of many human beings and also mutually sympathetic, helpful, and elevated relationships. For early men, this civilization (such as there was) went hand-in-hand with the crudely growing engineering arts. This was because the engineering arts enabled groups of people to become closely associated for the purpose of securing their safety of life and ease of living without sacrificing either existing conveniences or major comforts, as far as conveniences and comforts were then available. The group association of people proved the need of rules and customs of the nature of ethics and morals and a practical application of those rules to life. Generation after generation, with hesitations, recessions, and recoveries, somewhere in the world further steps in engineering improvements have been accomplished, with accompanying greater human intimacy and morality. The relations disclosed in our day show that there is still far to go before the goal is reached. Acceleration of the progress is desirable but all records of experience show that incautious haste in reform measures is a fruitful cause of confusion and that it actually tends to delay the pace of progress in its major ways. Let us be cautious!

Each step forward in the progress of invention looking toward security of life and property for early man gave further impetus to the tendency toward community living and this further forced a growing respect for simple mutual interests. However, it was only after the stimulus for making inventions had resulted in an easier life with regard to life security, food, and shelter, and also had released to individuals more time for cultivating physical ease, that growing ethical relations between man and man and tribe and tribe became strongly evident, and community living became smoother. The early aims of each human being seem to have included security (that is, safety for life and limb, sufficiency of food, adequacy of shelter from the elements) for self and family, such as characterizes the objectives of most mammalian animals. Then man gradually came to desire the permanent establishment of health, recreation, and contentment (or perhaps the correct word would be happiness) as part of his "place in the sun."

At the present period of our nation, our people are overdoing the shout for government-supported "security" maintained for individuals without aid of their own contributions accompanied by sweat of the face. Nevertheless, reasonable security of life, livelihood, health, and happiness is the stuff out of which civilization is made. Man has sought and still insistently seeks security of life with its concomitants, and also the greatest degree of convenience and comfort which may be derived from any given expenditure of energy; although, on occasion, he proves willing temporarily to sacrifice all of these.

When reflecting on this, we must remember that, as Sancho Panza says, "Good fare alleviates care." Engineering plays a strong part in meeting fundamental human aspirations. It is a human and intellectual affair. It deals with forces and materials provided by nature, and adapts them to human service for the satisfaction of human aspirations and needs as they are felt in each particular period; and in our period all commerce depends deeply on engineering. Gathering of raw materials, manufacturing, transportation, storage, and even the handling of goods, have become the children of engineering. Even farming (at least in America) has become permeated with the effects of engineering.

Stimulation of Needs

Moreover, as engineering achievements extend, the process of satisfying aspirations and needs stimulates human society (as individuals and as groups) to formulate additional aspirations, picture additional needs, and claim their fulfillment. One's needs seem to increase along with one's opportunities, and failure immediately to satisfy the seeming needs to the full causes disappointment that seems like suffering. To qualify safely under

such conditions, engineering must live under the guiding influence of the social philosophy of the successive periods, while always controlled by the restraints which characterize exact science.

This combination is a lively cause of friction. The stimulus of their aspirations and felt needs leads most human beings to press for an immediate fulfillment. This ambition often is encouraged and supported by theorists who have failed to observe that too great rapidity of change in social organization leads to ultimate harm instead of permanent satisfactions. Life in the aggregate is a composite of multifold relations and always has been. Revolutionary changes of social organizations usually leave a train of wreckage and hardship for all, including those most in need of improved conditions. Sound judgment demands that changes be made considerately, gradually, and with careful forethought. Thoughtful consideration is the way of wisdom. The records of history make these relations plain, but time does not permit the exposition of those records here. During the past 150 years our engineering improvements which are competent to afford convenience and comfort for all people have come rapidly forward, but our legislative acumen and foresight have not advanced in equal degree in the same 150 years. Alexander Hamilton wrote in the *Federalist* 150 years ago that: "Necessity, especially in politics, often occasions false hopes, false reasoning, and a system of measures correspondingly erroneous." Hamilton's pregnant cautionary words still carry a significance equal to the significance which they held in his lifetime.

Dangers of Ignorance and Prejudice

As citizens, we of this nation are proud of the education from which we profit. There is considerable justification for the pride, but instances arise which show that the results of education have not fully permeated among the citizenship even for the most elemental affairs of life. I will cite an extraordinary illustration which was disclosed to me as a bona fide occurrence. A married woman from low-income circles appeared almost annually at a hospital for delivery of a child until the family was an even dozen. Again she came, and (as she was leaving this time) the attending physician said, "I presume we will see you again next year." "No, ye'll not," said she, "me husband and me has just learned what makes them." This is quite on a level with the ignorance among some of the primitive aboriginal tribes of Australia and elsewhere, of which the natives "do not recognize sexual intercourse as a cause of conception" and give other specific causes.

If we still have in our midst such ignorance of fundamental biological phenomena which arise out of our personal intimacies, is it reasonable to expect a general sound knowledge of the less concrete phenomena of economics and society? Even our most expert citizens confess shortness in assurance regarding the latter phenomena. Therefore, the acute frictions (such as arise, for example, in the industries as a consequence of the close intimacies brought about so rapidly by the engineering inventions of the last two centuries) are likely to be the unhappy outcome of ignorance and prejudice. Such being the case, they are causes calling for sympathetic, man-to-man adjustment with such mutual forbearance as can be marshalled. The old-time destructive violence guided by violent minds, which was associated with industrial combats of my youth, is now outmoded in the minds of many of our citizens and must be brought to condemnation by all. Education which tends to the diffusion of truth, and thereby eradicates ignorance and prejudice may come to the rescue.

The factual and disclosing information which might enlarge knowledge and allay prejudice in this field is not readily available from books, monographs, and magazine articles. Fuller measures of factual disclosure are needed so that honest and adequate information may be before the public in general. Constantly applied, careful efforts at making facts known throughout the nation, in my opinion, is a shining means for forestalling the effects of ignorance and prejudice and for thereby ameliorating a sore spot in the social relations occurring as a consequence of engineering. An uninformed public usually is influenced by predetermined notions and prejudices; but the American public, when it feels itself rightfully informed and has had time to reflect on its knowledge, usually proves itself to be fair-minded. We are likely to forget that success in impressing the intelligence of great masses of people requires that clear, factual expositions shall be repeated again and again; although demagogic or inaccurate eloquence, once or twice expressed in fluent nonsense trickling from the speaker's tongue, may emotionally carry the same people into great error.

Work a Human Need

The inseparable relation of engineering to civilized society and to effective social adjustment is seldom given enlightened attention, and much of the fault of some ardently preached social doctrines is the result of popular misunderstanding of the true sources for enlarging material wealth. It is an unavoidable reality of nature that increases of permanent wealth are gained fundamentally only from what is grown on the surface of the earth, and taken from within the earth, from the waters of the earth, or from the air surrounding the earth; and that the processes of securing the wealth require muscular and mechanical power directed by the minds of men. For the populations to cease to work would mean that they would cease to live. We must keep industrious with minds and muscles or we cannot live in the comfort and plenty which is an ideal among western nations—evolved to different degrees in different nations but existing in all. It is important also to remember that joy in useful accomplishment, by the individuals composing a society, is essential to the realization of the best social adjustment.

How to incite joy in accomplishment is indeed a problem; but the engineering of machinery to lift long hours of

muscular labor more and more from the shoulders of men, associated with spreading mental effort more generally among men, is a promising path to the solution. Moreover, an increase of leisure which is so ardently desired by most people can be accomplished only by substituting in all practicable situations mechanical power for muscular power, by means of inventions which make the substitutions possible at moderate capital expense so that an extra margin of saving is produced, from which all concerned may profit. The phrase "all concerned" includes workers and customers as well as owners. It here is to be noted that scientific discoveries and engineering inventions which lessen the cost of useful processed products or which provide useful new products usually increase the rate of the production of new wealth.

Engineering is a process of planning, organizing, and executing work concerned with directing the forces of nature to the service of mankind; while the word civilization connotes well established, sympathetic ethical and moral relationships in society. The latter relationships develop only where considerable numbers of people work together for common ends, and means of community living or other community contacts are provided by engineering for the grouping of the people in harmonious unity and providing for their material needs. This must not be mistaken for communism. It is quite the contrary. Full civilization connotes harmonious well-being based on mutual sympathy associated with ethical and moral relations in society, while democratic independence of the individual is maintained to the limit of conscience expressed without external restraint. Communism, on the contrary, suppresses individual independence; and it may destroy mutually sympathetic relations while providing for livelihood in common.

The human mind, in mass, is very slow to change in character; and stable improvements of mutual relations cannot be rushed to success by the vaguely applied efforts of professional reformers or dilettantes in social affairs. Such improvements may only be successfully produced slowly, in association with sounder-growing mass thought regarding living affairs in both material and ethical relationships; and here the influence of engineering in showing the ways to material betterment is of primary importance. Following in the wake of material betterment and increased leisure, intellectual improvement also usually comes as an ultimate contribution to social welfare.

By living in ready contact with each other, we have come to recognize (in at least a glimmering degree) that the best living is when life is put to intelligent use in mutual advantage. We yet have much to learn before this is realized at a reasonable level, but ultimately we will be able to mold our engineering so as to achieve the wished-for ends. Sound progress connotes aid in bringing forward those persons who need aid and are willing to cooperate in the effort at aid. It also connotes unrestrained encouragement of the practices of those who are competently proceeding with ethical consideration along their individually chosen creative courses. This combination of connotations needs to be constantly emphasized.

Improvement in Living Conditions

One who studies with concentration the changes which have occurred in the living conditions of the populations of European nations during the last 200 years, or of our people during the existence of our own nation, must be impressed by the great change for the great proportion of the people from sordidness and insecurity of life and *livelihood* to relative security, comfort, and happiness. In these days, certain of our fellow citizens point to Sweden as a notable example of economic and social welfare. In a relative way, they are right; for Sweden has come forward in an admirable manner out of an age of sordid living and misery for most of its people. Means for ready and economical transportation, means for quick transmission of intelligence, means for generating and transmitting power, means for sanitation, and other great engineering achievements have changed the face of the people. The sordid and miserable have been raised and the disparities in security and happiness which formerly existed between the few and the many have been notably lessened by improving the lot of those formerly miserable.

The same miracle has occurred to the people of the British Isles, France, and other nations. The changes have beeen gradual but effectual, and they continue their course. The sound results have come from utilizing cautiously-applied measures for lifting the many. Where tearing down the superior economic and security status of the few has been practiced, it has always left in its train a legacy of disadvantages and misfortunes that affected people in all conditions of living.

Our experiences have not been without analogy to the experiences of European peoples and we may well examine the signboards of their history. We started later, with a pioneering people whose active utilization of their restless intelligence in a favorable setting did much for them. Our utilization of engineering achievements has been correspondingly active, and engineering invention has gone on at a high pace. The living conditions for our healthy and industrious citizens have been at a high level compared with the corresponding citizens of Europe. If one-third of our citizens are inadequately provided with food, clothing, and shelter (as viewed from our accepted standard of living) as has been alleged, I presume with truth, they are among those who need betterment and should be shown practical means by which they can come to betterment. But the precedents show that no general gain is secured by pulling down some with the object of raising others, nor by overfast efforts at general reforms such as have been pressed upon us during the past several years. Our social changes, if they are to be truly serviceable, must proceed at the pace which characterizes natural improvement of thought in an environment of encouragement and they must not be unethical, or our results in the end are likely to be adverse for those who should be helped instead of affording the betterment which is desired.

Politics in this country are seldom free from false slogans of which the unsoundness would be exposed by exacting analysis. We now are suffering from the effects of various

partially or wholly false slogans that relate to the fields of government, engineering, education, and security, which have been formulated to satisfy the supposed slogan hunger of the majority of mankind. For illustration, the false doctrine that civilization is decaying has been asserted again and again during the period from several thousand years ago to the present time and people still volunteer their ideas for saving civilization. The answer is plainly spread before us. If decay had in fact been going on over this long period, there would be mighty little civilization left with us today—instead of which we have in the best parts of the western world a civilization which is superior, in the sense of being more comprehensively helpful to man, than that existing anywhere in any of the preceding centuries. This statement rings true when it is tested by comparison of today's conditions of the great mass of people with earlier conditions, whether two generations, two centuries, or 2,000 years back.

If moral relations and security of life mean anything in happiness, as most of us believe, there is more happiness in this country today than heretofore in any country of great population. There certainly are more comforts in life than in any earlier time, and more leisure for most people, mostly brought about by engineering applications of science. And even from this level, progress continues in a clear pace. Trying to overaccelerate that pace by poorly conceived political nostrums harms instead of helps. Efforts put forth to save civilization are only folly and are not needed. What are needed are efforts to deepen and enrich the spirit of sympathetic understanding between men, so as to better the conditions for negotiating the amelioration of those differences which may injuriously arise because of our more constant and intimate mutual contacts.

Influence of Engineering for Peace

Engineering processes and engineering devices have been (and are being) abused by use in warfare, but not by choice of the leading minds of the engineering profession. The profession, with few exceptions, stands on the conviction that war is tragic, expensive, inefficient, and unnecessary. However, as world affairs display themselves, we must be prepared in an organized way as a nation to stand against aggression from without in case aggression should arise in spite of friendly negotiations planned to prevent forcible action. Convince man that war will not ultimately result in greater wealth, security, and stability for him and his nation and the tendency toward organized war will be weakened. Especially will this be achieved if other sufficient routes are kept open on which men's love of risk and adventure can be fully expended, while the paths to selfish profit during war are closed. It lies with us to hold so steadfastly to the duty of more fully developing the peaceful occupations of agriculture, industry, and commerce that the minds of our people may be turned away from contemplating aggressive expansion and warfare. Engineering favorably influences all of those peaceful occupations, and we engineers have an obligation to ourselves and our fellow citizens to encourage the highest practicable development of these ethical aspects of engineering.

That is the attitude of engineering in this aspect of its social relations. The defects in human relations which arise in local, national, and international affairs are due neither to faults in the fundamental ideal of a complete civilization, nor to engineering which has set up and continues to maintain the stage for a possible realization of that ideal. A grave responsibility rests on critics of our status, who are failing in the call for agitation and education of the public to a realization of the relative fitness of things. This is a personal and group matter to achieve, and it cannot be achieved by partisanship or foul play.

Much has been accomplished in the long-time development of civilization. Much is yet to be accomplished. The accomplishment cannot be secured in any nation by legislation alone. The solution can be obtained by joint use of two paths.

One of these leads to continued emphasis on sympathetic negotiations between man and man, or group and group, before going to extremes. Much progress for our country has been made in this path during the past half century. Such progress has been notable in our engineering industries, but it is yet insufficient, and more sympathetic relations must be fostered. However perfect a coin may appear on one face, if it is suffering from corrosion on the other face it is defective and needs reminting. Social reminting in an engineering world with its democratic qualities, however, requires a depth of consideration and range of cautious adjustments which immeasurably transcend the requirements for the machine-reminting of coins.

The other path leads to the joint problem of education in engineering and political economy which now is crying for solution in order that the social problems may be smoothed and society aided to make progress in the best sense.

Our national needs are, on the one side, a moratorium on loosely drawn legislation, careful simplification of laws which we have, and, primarily, emphasized efforts to make ethical principles a guide in both the observation and the administration of statute law. Abstract justice is an ideal, but enforcement of law according to ethical principles can be made a very practical thing.

On the other side, our national needs include a careful nurturing of the results of scientific research and discovery in the fields of natural science and of so-called social science, which may stimulate engineering invention and engineering practice out of which still further improved living conditions may arise. Many endowments for research in natural science and in economics and sociology exist, and our need is for an endowment to promote the study (including research and exposition) of the joint relations of engineering and political economy, having for its purpose the establishment of an understanding of the most helpful relations which may be built up for a prosperous social welfare. This is a need indeed, and a donor can make the nation his never-ending debtor by establishing an endowment to this end.

Dugald Caleb Jackson—1938 Edison Medalist

By J. W. BARKER
FELLOW AIEE

A summary of the accomplishments of the current recipient of the Institute's highest honor reveals a balance between work as a consultant and as an educator

THE life and achievements of the 1938 AIEE Edison Medalist illustrate the nearly perfect interweaving of two great fields of activity, the work of the consulting engineer and that of the engineering educator. Even at the risk of his own health by burning the candle at both ends, Doctor Jackson has made glorious contributions to both fields and has maintained an even balance of the scales. He has demonstrated the desirable cross-fertilization which is possible only when the two careers develop side by side.

Born at Kennett Square, Pa., on February 13, 1865, he was graduated in 1885 as the "class baby" with the degree in civil engineering from Pennsylvania State College where his father, Josiah Jackson, was the professor of mathematics. After completing two years of graduate study in electrical engineering at Cornell University, he and two college friends, J. G. White (later the founder of the far-flung J. G. White interests) and Harris J. Ryan (later head of the electrical-engineering department at Leland Stanford University and director of the Harris J. Ryan High-Voltage Laboratory) founded the Western Engineering Company at Lincoln, Nebr. His pioneer experiences in this company, constructing early electric railways, building electric power plants, and other practical engineering work, together with his close association with two other brilliant minds of diverse types, did much to develop the broad engineering judgment which has characterized him throughout his life.

In 1889 he became assistant chief engineer of the Sprague Electric Railway and Motor Company, installing some of the earliest electric railways in the United States. Then he was appointed chief engineer of the central district of the Edison General Electric Company, but in 1891 he was called to the University of Wisconsin to become professor of electrical engineering and organize the department. In 1907 he went to head the department of electrical engineering at the Massachusetts Institute of Technology, where he remained until his retirement in 1935.

His engineering accomplishments are so numerous and significant that they alone would mark any great man's career. Shortly after he went to Wisconsin in 1891 he organized with his brother the consulting firm, D. C. and Wm. B. Jackson. This firm continued until 1918 when the services of the partners (a third partner had been added in 1916) in the World War caused it to be discontinued. During this period the work of the firm was largely with electric light and power companies, particularly in rate matters, questions of organization, design of generating and distributing plant, and various problems of operation and development. A considerable amount of work was also done for the public utility commissions concerning supervision and control of electric light, power, and telephone companies. One of the most interesting tasks and one of which Jackson was most proud, was an engagement by the British Government Post Office Department to guide them in taking over the property of the National Telephone Company in 1911. Jackson had been chosen for this by a special royal commission which had visited the United States the preceding year.

Service During the World War

During the World War, Doctor Jackson was major and then lieutenant colonel of engineers, charged as chief of the technical board with the procurement of the power supplies for all American war activities in France outside the actual fighting zone. Decorated with the Legion of Honor for this work, he was retained after the Armistice as chief engineer of a special board of the peace conference to evaluate the war damage to physical property in all the Allied countries. Under General McKinstry, this board had eventually upward of a thousand specialists. It is worth telling of his appointment as chief engineer as illustrative of *why* preferment as an engineer and as an educator so often came to him. When he reported to General McKinstry he found a group of some ten other officers, many senior to him, already there waiting for something to start. General McKinstry called them all together and requested that they work singly or in pairs to prepare plans for carrying through this immense project. Many of the other plans were rather perfunctory, indefinite, and meant little or nothing. Jackson's report was complete, giving outlines of classifications under which the properties were to be grouped for appraisal, methods for handling the appraisal of each group, approximate methods to be used when accurate data had been destroyed by the war, personnel required, transportation needs, some idea of the time necessary,

Prepared especially for ELECTRICAL ENGINEERING.

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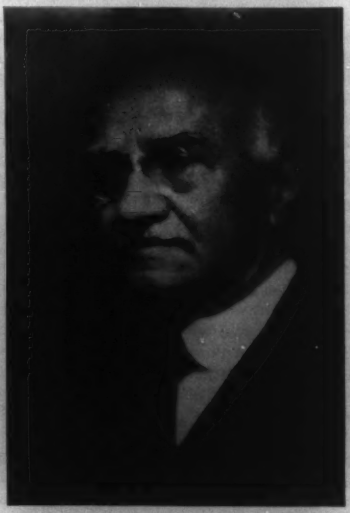
and an estimate of the cost. Two days later he was appointed chief engineer and some of his seniors in rank wondered why! We who worked with him know why! Possessed of one of the most remarkable memories for all kinds of facts, with an uncanny ability to sort essentials from nonessentials, with a keen analytical ability to get to the heart of a problem, with great powers of concentration and the ability and willingness to work indefatigably, he could and did synthesize such clear, persuasive statements of even a most complex problem like the war damages that his reasoning was followed and his conclusions accepted. This truly formidable array of characteristics marked the man in all his work. There was a common saying in his various offices that after an hour with a report Doctor Jackson would know what there was in the report better than the man who wrote it.

Return to Engineering

Following his return to the United States in 1919, Jackson resumed his professorship at MIT and reorganized the consulting firm with Edward L. Moreland, a former student and partner in the old firm, as partner. Many important engineering projects were handled by Jackson and Moreland, such as Conowingo (favorably reported upon and later built by others), Passamaquoddy (adversely reported upon—and not *yet* built), the 75-mile main-line single-phase a-c Great Northern electrification through the Cascades using a-c d-c locomotives, the Delaware, Lackawanna and Western d-c suburban electrification out of Hoboken, N. J. (both of which were planned and built under the supervision of Jackson and Moreland), and other consulting projects on generation and distribution too numerous to mention in detail—engineering accomplishments of which any man might be justly proud and which would merit the Edison Medal award.

Running all through these activities I have mentioned have been also outstanding contributions to our professional and educational societies—member and past president of many, he looked upon two such offices as opportunities for real contributions. President of our own American Institute of Electrical Engineers in 1910–11 and member of the board of investigation and co-ordination of the Society for the Promotion of Engineering Education, these offices gave him an opportunity to impress his personality and his philosophy upon the engineering and educational worlds.



Doctor Jackson

Jackson's career has been equally distinguished in both phases. Of the two, however, I believe that Professor Jackson has found deeper and more abiding satisfactions through the educational phase, although greater monetary return and somewhat more prestige through the consulting. He has always maintained the desirability of such a double career for engineering educators, since the practical experiences gained in consulting contribute greatly to the enrichment of the teaching. At the same time he has always recognized that proper engineering research for the educator has the same enriching effect on the teaching (and Jackson has conducted much personal research. He has been "starred" in American Men of Science for many years).

Educational Philosophies

Professor Jackson early adopted three basic educational philosophies which have been marked by outstanding results. The first of these was that students should be brought as soon as possible into contact with the unknown, thus stimulating them to think for themselves, instead of drilling into their memories only the cut and dried principles of the textbooks. Yet so well balanced was his judgment and ability that he wrote at least three of the earliest and best known texts on electricity and magnetism and a-c machinery, so fundamental and so thorough in their treatment that they retained their popularity for more than 20 years. I think this illustrates one outstanding characteristic of Doctor Jackson—he doesn't ride his hobbies so hard or so fast that he fails to keep a rational balance. This student contact with the unknown can only be brought about by a teaching staff which engages in consulting practice or research. Consequently, Doctor Jackson has always encouraged the members of the staff of his department to undertake one or the other of these collateral activities.

A second philosophy or objective has been the creation of a practical system of co-operative engineering education in which the students for three calendar years alternate between semester periods of technical instruction in the engineering school and semester periods of paid but carefully chosen closely supervised industrial work continually increasing in responsibility and fortified by technical engineering instruction two evenings per week. It took many years of painstaking contemplation and statesmanlike negotiation with industrial leaders and faculty to bring this objective to fruition, for not until

1919 at the Massachusetts Institute of Technology did the time seem proper and the industries seem ready to accept a plan which differs so radically from other cooperative plans where the practical work is largely for revenue. This marks other outstanding characteristics of Doctor Jackson—his willingness to wait until the time is ripe for an innovation, his keen sense of when the time *is* ripe, and his ability to negotiate.

The third philosophy has to do with the exceptionally able student. Jackson worried for many years over the seeming defect of the American system which tended to retard the brilliant student to the pace of the average student. Finally he evolved a program modeled along the lines of the English universities' "honors system" but thoroughly recognizing the differences in the two educational systems. The program involves sectioning of all large classes into small groups based on equivalent mental speed of the students, culminating in one group known as the "honors group" who are relieved of all stated class meetings but held responsible through a truly comprehensive examination. This program has now been in effect for some 12 years at MIT in the electrical-engineering department with exceptional success. In this program Jackson found an able enthusiastic collaborator in Gerard Swope who also was interested in the possible application of the English system to our American technical education.

Departments under his charge grew and expanded to notable size, yet Jackson never lost sight of the fact that he was more interested in individuals than in curricula or even subject matter of courses. Busy as he was with the multitudinous duties of an educational executive with between 400 and 600 students in his department, together with his extensive consulting work and his activities in the professional societies, he was never too busy to consult with a student or staff member on any real problem, technical or personal, and to bring his warm personality, rich experience, and cold analytical ability to help toward a solution. Scornful of half-baked ideas and poorly thought through plans, many an associate has been almost literally blown out of the office to think the whole matter over again, yet Jackson was ready with a pat on the back and warm commendation for a task well done no matter how small.

Pride in His Students

I am quite sure that his greatest pride today is not in any one of the many engineering works with which he has been connected but in the multitudes of young men who, having studied and worked under him, have gone out into the engineering, business, and educational worlds stamped with something of the Jackson hall-mark. I recall a summer convention of the AIEE at the New Ocean House at Swampscott in 1929. The Chief had been suffering terribly with a rheumatic attack in his arm. The evening of the banquet the nine others at his table noticed that he was particularly quiet, a bit glum, and did not enter into the otherwise vivacious conversation. He was absorbed in the seating list, and finally began to smile very satisfiedly. Mrs. Jackson said, "Well, Dugald, what have you been thinking about?" and his reply was, "Now, Mabel, do you realize that there are some 50-odd former students of mine in this very room tonight who are presidents of the Institute, past presidents, deans of engineering colleges, heads of departments of electrical engineering, or chief engineers of their companies?" His obvious pride and gratification in the success of "his boys," of whom I am also proud to be one, is proof of my assertion that building men is his greatest satisfaction from a long life of hard driving work.

To epitomize him I can do no better than to use the phraseology of that incomparable master of the citation, President Nicholas Murray Butler of Columbia when he conferred on Professor Jackson the honorary degree of doctor of science in 1932, with these words:

Native of Pennsylvania, and trained at Pennsylvania State College and at Cornell University; closely uniting industrial experience with scientific research, and, after 16 years of service at the University of Wisconsin, passing a quarter century ago to the department of electrical engineering at the Massachusetts Institute of Technology; active in a score of ways as engineer, as educator, and as administrator; honored at home and abroad for distinction of mind and of service marked by broad vision, boundless energy, and vigorous leadership; a true ornament of our country's scientific endeavor and of its educational force.

Illumination Notes*

Fluorescent Industrial Lamp. Out of the laboratory has come a new, highly efficient 100-watt lamp for industrial lighting. Like the well-known long-tube Cooper-Hewitt lamp, the new lamp is a four-foot tube containing a low-pressure mercury-vapor arc; but the new feature is a fluorescent coating on the inside wall of the tube, which converts the ultraviolet radiations of the arc into light. The efficiency is 50 lumens per watt, about three times that of the corresponding incandescent lamp.

Projector Lamps. Decidedly novel types of Mazda lamps have recently been announced. They are projector lamps having incorporated in the bulb an efficient reflector consisting of a metal coating on the inside of the glass. The reflecting surface is accurately shaped and the filament accurately positioned at the focal point. One type called the "projector lamp" is made with two beam widths. One, giving a strong narrow beam, is designated as the "projector spot lamp;" the other, with a wider beam, is called the "projector flood lamp." The lamps fit the ordinary socket, and are made of hard glass so that they may be used outdoors as well as in. Still another type, with narrow powerful beam, is made of soft glass, for indoor use only. It is known as the "reflector lamp."

* Contributed for the AIEE committee on production and application of light by L. A. Hawkins (A'03, M'13) executive engineer, research laboratory, General Electric Company, Schenectady, N. Y.

The Balancing of Incentive and Security

By RALPH E. FLANDERS

Certain conditions and trends relating to incentive and security are discussed in this article, which suggests that consideration should be given to various possibilities of stimulating interest toward higher standards of living as well as security.

THE choice between security and incentive is presented in numerous fields and on many scales. This choice has to be made by individuals, by businesses, by industries, by social groups, by nations, by whole civilizations. Nature herself, in the long process of the development of life, has experimented with both principles, offering individual or group security to some species and insecure initiative to others. A consideration of the evolution of living things from this standpoint would be a most interesting undertaking and would be of suggestive value in the study of related human problems; but time and space are lacking for carrying out such a project.

It is proposed that the field of inquiry be limited to these few relationships: that of the individual or organized worker to industry and to organized society, and that of organized society to the destiny of western civilization.

In the first place, not incentive alone with its policies of enterprise and risk, nor security alone with its attitudes of defense and protection, can be considered as satisfactory conclusions of our inquiry, whether for persons, businesses, or government. The taking of too great risks may result in the destruction of the gains of the past. Too great a concentration on security will lead to the wasting away of former achievement and a decay of present advantage. There must needs be a proper balance between incentive and security. Both are necessary. The question before us is to determine what is the proper balance; or, if that be impossible of determination in satisfactory terms, to see as clearly as we can what are the factors which lead toward the determination of the proper balance.

Comparison of American and European Business Organization

One of the most interesting examples of a difference in attitudes toward this question was plainly to be observed in comparing the American and the Continental business organization in the pre-War period. It was then the experience of most of us who were engaged in the manufacture and sale of high-production machinery, that the attitude of the European customer toward our product differed fundamentally from that of the American prospect. The European of that time lived in what seemed on the surface to be a settled civilization. The foreman or shop superintendent or managing director had arrived at a certain place in the social scale. Having attained that place in a well-ordered civilization, he was more deeply concerned with maintaining it than he was in risking it for the sake of possible future advantage. When confronted with an apparent opportunity for making greater profits by the expenditure of large sums of money, his first and strongest reaction was that the expenditure of those large sums was a dangerous undertaking. While it might prove to be advantageous in the long run, yet again it might not. A single serious mistake would jeopardize his position and cost him his assured place in the social scale. There would probably be no complaint whatever if he did nothing; while there was a large chance of failure and consequent disaster if he took the risk. Under these circumstances the normal attitude of that day in thousands of business establishments was that of letting well enough alone. Security triumphed over incentive.

In the America of that day, on the contrary, amid the confusion and turmoil of expanding population and expanding industry, the rewards of place, power, and income went to those who were willing to take risks. So many men of ability were willing to take risks and the risk of failure was so far below the 50-50 margin that those who did take risks as a whole surpassed in the race those who did not. The atmosphere, therefore, was one of incentive.

The author's observation is that a comparison of present-day conditions as between Europe and America reveals much less difference than was apparent 25 years ago. The European social structure is not so well ordered. The security of the inactive individual is less assured. The obvious rewards of initiative and risk are greater. On the converse, in the United States there has been a tendency to take the mature point of view. With the disappearance of the physical frontier and the leveling off of the population curve, the obvious and automatic incentives to expansion are diminishing.

It is not a part of my purpose to explain why I believe that these factors do not of necessity call for a slowing up in our expansion of activity for the next generation; but the fact remains that they are at the moment effective. They are particularly effective when combined with laws and policies of our federal government which dampen enterprise and exalt security; but of these more

Essentially full text of an address delivered at the Seventh International Management Congress, Washington, D. C., September 22, 1938.

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later. The net result is that the heightened spirit of enterprise in Europe and the lowered industrial vitality here tend to bring the two regions more nearly together than at any time within the memory of men now living.

Two Types of Workers

This problem of the proper balancing between incentive and security affects the relation of the business to its working force in all its ranks, and not simply with relation to those in management. Probably most of us concerned with management have come to the conclusion that there are two broad categories of employees. One is the routine worker whose principal desire is for steady work at good pay. The other type, much smaller in numbers, is spurred by initiative and desirous of assuming responsibility and of expanding his responsibility to the limit of his powers.

These two classes considered in their broad human aspects do not constitute an inferior and a superior class. Both are necessary to industry. If all of us were in one or the other, industry could not survive. Especially should it be remembered that the larger group which looks primarily for security in industry is not the inferior class of the two. In mental equipment, in moral sensibilities, in capacity for the highest satisfactions of life, there will be found at least as many superior individuals among those looking for security as among those spurred by incentive. Industrial management and responsibility is after all a highly specialized form of human activity. Those who are fitted for it are not thereby picked out as being superior human beings. They are simply better adapted to a specialized range of human activities. Let us not make the mistake of concluding that excellence in our particular field means corresponding excellence in the general scale of human character.

A practical management problem arises in determining the amount and kind of incentive to offer this group which constitutes the larger portion of the employees of the individual business. There are limits to the money incentive which can be applied from the purely mathematical standpoint of cost per operation, per piece, or per pound. The limits in desirable income stimulation in fact fall well below this mathematical maximum. Any wage incentive which keeps this group unduly stirred up, whether by unnatural physical or mental effort on the one hand, or by fear as to the security of the wage arrangements on the other, is bad management in the long run whatever the short term effects may be. It is important for these workers that their connection with industry shall be such as to lead to tranquility of mind and self-respect in their position, whether at work or at leisure.

But while there are limits to the monetary incentive, there are no limits to the intangible incentives which may be offered. The greatest available security of employment and of wage income both as determined by private business policy and by the stabilization of our economy are requisites for satisfaction in life to the great body of our fellow-citizens in industry. Those who have lacked opportunity to become acquainted with the workman for whom these conditions have in some measure been provided, will never understand the prideful relationship between the worker and his work which exists among them. The expansion of the conditions in individual business and in our economy as a whole which make this relationship possible will add immeasurably to the general happiness of the nation.

The smaller group is one endowed with initiative and a willingness to take on responsibility; and from this smaller group the ranks of industry leadership are recruited. Such leadership is at its best when, either as viewed individually or as a class, it renounces complete security for itself, but is deeply concerned with security for those in its charge. If that leadership is wise, its own initiative will be tempered by cool judgment and by experience; but yet it will always find itself functioning in accordance with a temperament which reaches out for anything which is unknown and untried, provided it be rationally hopeful. Unless there is enough of this latter element in its mixture of qualities, the interests of those led and of society as a whole will not be best served.

Decline of the Capitalist

The individual positions of the old-fashioned capitalist group continue to become less and less secure as time goes on. In the United States, at least, the heavy incidence of estate taxes and the continued multiplication of the number of stockholders in a given enterprise tend year by year to take the management of our productive wealth out of the category of inherited wealth and put it into a separate management class. We may almost say that the day of the capitalist has passed. Ownership is no longer as a rule vested in powerful individuals. Ownership is continuously more subdivided and fractionated. The opportunities of management are increasingly more and more open to those who can gain them only by other means than by inheritance. This condition is true even though it is possible to point to remaining individual capitalists of the old type. Their number and their importance diminishes yearly. The new profession of nonowning management grows in importance. The means by which high position in management is obtained does not, of course, always assure the best possible men for the work; but the standard is surprisingly high, and there seems to be no doubt as to the desirability of the existing management class as compared with inherited managership as we have witnessed it in its decline. Again, of course, we are using broad general terms, bearing in mind many brilliant exceptions to the general rule.

It would not be proper to leave this topic without calling attention to a third type of fellow human-being —the person who has willingness and even anxiety to accept responsibility, but is unequipped by nature to take it on. Such individuals offer a difficult problem not only to management but to themselves. Sometimes they are persons of ability who have mistaken the nature of those abilities, in which case the remedy lies in redirecting their ambitions and energies. Here it is evident that

the bare application of incentive is of little avail. The great need is for analysis and redirection.

Sphere of the Labor Union

The labor union occupies another sphere in which choice has to be made between security and incentive. In some industries the emphasis has been so strongly on security that wage rates and working conditions have been set at a level which decreases the volume of work which is available to that industry at prevailing costs. The result is that those who have work under these conditions fare far better than in the past, but meanwhile many of their fellows are needlessly unemployed and the whole business machinery runs at an unnecessarily low rate of output, employment, and total pay rolls. Thus the whole country falls below the general standard of living of which it is capable.

This represents an extreme of labor-union policy which in its normal and socially needed function is altogether helpful. That necessary function relates to the correction of the evil situation found in industries in which the competition between business organizations is primarily on the matter of wages, thus tending to grind them down to the lowest possible limit. The solution lies in reversing that process by labor-union activity and replacing it by competition in equipment and management whereby high wages can be paid, low prices maintained, the general purchasing power increased, and the standard of living raised.

So far as the industries themselves are concerned, they are seeking a false basis of security for themselves in driving wages down and, in addition, they set up thereby destructive forces in the whole fabric of society. The remedy lies in the direction of greater risk in investment and a consequent insecurity in first appearance. But in the end this provides for the business, for society, and also for the employees far greater security than can ever be obtained by the more reactionary policy.

We must be careful to remember, however, that undesirable labor-union policies are but a reflection of a corresponding policy which has been attempted over and over again by management in industry. Individual businesses who fancied that they were strong enough to do so, either by their temporary dominance of the market or by patent protection or other real or imaginary advantage, have endeavored to capitalize on that advantage by raising the price of the product and trying to get an unduly large profit. Such an attempt at gaining financial security is seldom successful in the long run, even when made by strong groups of manufacturers instead of by individual companies. There is in high profits a strong stimulant to opposing enterprise. Small new firms dig into the market. New inventions and devices come to light which parallel the older ones and injure their monopoly value. Sometimes completely new products are devised which blanket the wind from the sails of the going enterprise, and cause it to fall behind in the race.

This is particularly the case when an old industry endeavors to protect itself. Human ingenuity is limitless, and the endeavor to secure monopoly seldom fails to produce competition of unexpected strength and novelty. In the long run the industry which seeks to secure its position by monopoly and raised prices finds itself at a disadvantage as compared with those industries which work on a lesser margin of profit but depend on energy, good service, and moderate price for their safety.

The best solution, so far as concerns the general prosperity of a country and its standard of living, is thus the same for organized labor or organized industry. The proper balance between security and incentive must be maintained.

The Paradox of Security

What has been said as to the balance of elements between individuals and business organizations, and as between business organizations with each other, applies with full force to the relationship between the individual and organized society. But here we meet with some additional elements of very great importance. One point relates not only to the continuously recurring question as to the proper amount of emphasis to be put on incentive and security, but raises the further question as to the types of experience and activity to which each should be predominantly applied.

Upon examining the course of the history of our civilization, we are faced with a paradox. The succeeding centuries of its development seen in one aspect appear to provide greater and greater security as time goes on. In another aspect the history of the western world seems to be a progress toward more and more delicate balance and greater insecurity.

If we examine the structure of our society, we will discover that the growth in security relates mostly to material things. Civilized nations are less and less subject to famine as the generations pass by. Greater output per acre and per man, crops somewhat less dependent on the weather than in times past due to irrigation and improved methods of cultivation, the elimination of a large percentage of disease and death and even of accident by improved hygiene, medicine, surgery, and safety practices—all these represent consistent gains in security.

The increasing delicacy of economic balance is likewise plainly evident; so evident indeed as to be appalling. This is due to a number of causes, among which are the following:

1. Present-day restrictions on freedom of trade between sovereign countries have restricted the flow of commodities from regions of plenty to regions of dearth, so that local depressions are less easily compensated for.

2. Our money has of necessity shifted from a gold to a credit basis, and in so doing has become dependent for its volume and velocity of circulation on psychological factors which are difficult of control. "Business confidence" cannot be made to order.

3. The spread of popular education has done its part. Hundreds of thousands and even millions of people are following the business

indices who 20 years ago did not even know that they existed. Their purchases are going up and down with the stock market. They no longer act like the classical "economic man."

4. As the standard of living is raised, a larger and larger per cent of the expenditures of the mass of the population goes for goods whose purchase can be postponed. Not only *can* the purchases be postponed, but they *are* postponed, and billions of idle dollars are on occasion hoarded in our banking system that would be in active circulation if the holders of these funds were under any necessity for spending them.

5. The very temper of our civilization is that of tension; and the hair-trigger temperament that goes with our life plays its part in the sudden and unpredictable movements in mass psychology which affect all of the preceding elements.

Truly we live in a delicately balanced society; or perhaps we had better say, in a society perpetually unbalanced and endeavoring, sometimes unsuccessfully, to maintain its equilibrium.

Mechanical Analogy

If we look for a material analogy to this social situation, we find it in the progress of science and engineering. We may, for instance, examine the development of the means of transportation and find it at once becoming more perilous in its possibilities, while at the same time, it becomes ever more safe so far as concerns the actual number of disasters. When man made his way only on his own feet, he was free from innumerable possibilities of accident that went with later modes of travel. Yet the broken leg or other similar accidents must have been of frequent occurrence. When he took to riding on horseback instead of traveling by foot, the number of kinds of possible accidents greatly increased; yet if statistics had been available, it might have been found that there were fewer accidents per horse mile than there were per man mile for the pedestrian.

Perils were tremendously increased with the advent of the railroad. The automobile still further increased them. In fact, our speed and the traffic conditions with which we have to contend, if viewed by anyone seeing them for the first time, would seem to be a wholesale invitation for wholesale slaughter. The accident rate is far too high. It is marvelously low when we consider the possibilities for trouble inherent in the situation. And that low rate is at last beginning to turn lower yet as the driving population becomes more and more skilled in the handling of the car and more and more imbued, by social pressure, with the necessity for carefulness.

The automobile, or the older railroad train, is by no means the most recent development in combined insecurity and safety. Travel by airplane is of all imaginable things the most insecure and the most subject to sudden death and destruction. Yet the figures for accidents per passenger mile on regular commercial flights are astonishingly low—incredibly low. Here we have the combined counterbalancing effect of mechanical improvements and human organization in rendering reasonably safe a means of transportation which, exhibited for the first time, would appeal only to the foolhardy and the reckless.

May we not take some hope in this mechanical analogy and feel that the increasing instability of our society does not debar us from making it increasingly safe by corresponding improvements? Those who refuse to consider these possibilities are fond of saying that you cannot go against natural law. This we cheerfully admit; but within the realm of natural law innumerable novelties have been devised and innumerable successful devices have resulted from the trial of those novelties. This does not mean that in the social field we can safely trust to haphazard experiments. The risks are too great, and a single disaster may have appalling results. It does mean that the application of the same kind of analysis and design to social problems that is applied to the solving of the engineering problems of the airplane may produce comparable results. It may not be hopeless to look for the application of social devices which will prove as effective in promoting the normal operation of our social mechanism as was the simple expedient of giving a dihedral angle to the wings of an airplane in giving a needed degree of inherent stability to the craft when it is in flight. So much for the possibility of the existence side by side of growing instability and increasing security. Let us next ask ourselves over what areas of our social existence should security be applied, and what areas should we leave to the influence of incentives?

Application of Security and Incentive

As one suggested answer to this question, may we not make a division in accordance with the age of the individuals who make up the great body of our fellow citizens? It is within the physical capacity of our civilization, either operated as a whole or in groups or units in part self-sustained, to provide for the population the following kinds of security:

For youth, we seek preparation for life's work and the broadest range of opportunity that it is possible to provide. Nature does not provide equality of gifts and abilities. No social organization has as yet successfully provided equality of income or equality of ownership, unless it be on the basis of a very low standard of living. What we can hold before ourselves as the ideal for youth is the nearest possible approach to equality of opportunity. This is a right possessed by the individual in a democracy. It is more than a right. It is a necessity for the perpetuation of democracy, if democracy is to be perpetuated and if society is to move on to higher service for the individuals who compose it. We cannot afford to allow any talents to go unused and undeveloped. We cannot permit any abilities to lie undiscovered. We must prepare for an era of great expansion of education, not in its mere bulk so much as in the development of new kinds of education to fit more kinds of people in all kinds of situations.

We are, moreover, faced with an emergency which requires that we act now in this matter. With the present varieties and distribution of education, the great majority of students do not carry their schooling beyond the grades. Of the remainder, the majority get through our present

high-school courses with difficulty. In the meantime, the age at which the boy or girl may go to work has been raised to 16 years and present tendencies will bring that minimum age before long to 18 years or even older. These empty, unoccupied years at the critical period in the life of the boy or girl constitute a serious menace, not only to the character development and future of the individual, but as well to the state and nation of which he or she will become an effective ruling element under our form of government. This educational problem must become a matter of first importance to us. The youth must be secure in preparation.

At the other extreme of the life span, we have entered a new period of responsibility for old age. It has become a part of our social purpose to see to it that those who have worked faithfully during their years of strength shall, during their years of retirement, be assured of adequate food, clothing, and shelter. This minimum responsibility society is sharing as an obligation with the individual. In so doing we will relieve the middle years of unjustifiable worry for the future, leaving them free to be devoted to the productive occupations by which the programs for youth and old age will be sustained. Age following a productive maturity deserves security.

We have made real progress in these last few years in defining and accepting our social obligations to youth and age. We have failed in developing the policies and institutions, and even the proper mental attitudes, required for such a direction of the productive years of men and women as will make it possible to support these new obligations for youth and age. It is in the reviving and freeing of the effort of the working years that our nation finds its duty and its opportunity.

It is in the middle years that the full force of incentive must be provided and applied. Some security for unemployment, accident, and illness must be provided. But the whole atmosphere of maturity must be that of production, self-support, and the support of society as a whole. But even here, as we have seen earlier in analyzing the different types of workers, the full stress of incentive cannot properly be applied to every individual in the middle years. Personal responsibility for personal well-being must be made possible and emphasized. But the full force of incentive must be left to fall on those who are to lead and direct the needed expansion of our productivity.

For the United States alone, it is the conviction of your speaker that the spirit of enterprise and the response to incentive has been greatly diminished in industrial and mercantile leadership in the period since 1929. This spirit did not revive with anything like its old vigor even during the relatively prosperous year of 1937. Many reasons can be and have been offered for this condition.

The physical frontier has disappeared; the population curve is flattening out; and automatic, irresistible stimuli to business expansion are no longer available. These facts, more or less clearly realized, have perhaps tended to produce a state of pessimism in the minds of American business men. If so, it is a quite unnecessary condition. The physical resources, technical progress, and numbers of our population permit of a great expansion in the standard of living and will require a great expansion in industry to meet it; and it is on this possibility that we must fix our minds. We cannot examine the possibilities too often or point them out too insistently.

The other group of deterrents to a revival of initiative has come from government. On the one hand is the limited point of view of the social worker whose mind is fixed on security alone. On the other is the politician who finds the easy road to maintenance of power that of the promise of security. Security is a much easier thing to provide on a temporary and spectacular basis than is the much more fundamental achievement of a raised standard of living.

What we have to learn is that *there is no long-time security without incentive and initiative.* For a continuance of achievement in our western civilization we must strike a balance between the two policies. We are like an army with new territory ahead of us. If it is unwise to extend the front line too rapidly lest our communications be cut off from the rear and our army destroyed, it is equally unwise to go into a permanently fortified encampment in our present location. This is not a good place to stop.

In view of the physical, technical, and human possibilities ahead of us, it is a primary duty of government to bring about within the governmental field the conditions which foster a revival of initiative and enterprise. Our present need is not alone for security but for incentive. On the return to incentive hinges the success of our whole effort to attain a possible and desirable advance in the security of the whole mass of our fellow citizens.

Westinghouse Photo

Engineering Opportunities in Manufacturing

By T. C. JOHNSON
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Electrical manufacturing offers many opportunities for the engineering graduate. Broad, intensive fundamental training rather than specialization is required, because co-ordination of knowledge from various branches of engineering is required. The scope of positions in the industry, ranging from technical to nontechnical by successive steps from research to sales and advertising, is outlined in this article.

ENGINEERING as a profession offers a variety of opportunities in many lines of endeavor, but probably no one other field offers as wide a variety as that of electrical engineering. A statement quoted from the bulletin of information of the Columbia University school of engineering says: "A young man may have in high degree the qualities which in general are essential for an engineer and yet may not have the type of mind which is necessary for the successful practice of electrical engineering on its technical side. There is required a quality of mind and imagination which is able to visualize into practical form the results of electrical theory. It therefore follows that the mind should be of a type to which the analytical theory is not repugnant. Owing to the great and rapid advance in theory and practice, anyone with a strong conservative tendency is at a disadvantage in electrical engineering."

In this article the relative importance of the electrical manufacturing industry to the engineering profession, the diversity and scope of the many possible engineering positions which produce the great variety of electrical apparatus, the interdependence of this industry with many other fields of engineering which have influenced its growth, and the type of educational training this industry demands will be discussed.

To orient the reader, the size and position of the electrical manufacturing industry in relation to the other manufactures of the nation will be investigated. According to the most recent available census reports (1935), the electrical industry furnishes about 2.5 per cent of the total value of manufactured goods. This places it about eighth in rank, being surpassed only by such others as the automobile, steel mill, and petroleum-refining industries. Ranked according to number of wage earners employed it is seventh, while it is third when compared on the basis of value added to the products in manufacture. Only the steel and printing industries add a greater fraction of the total value of their products by the process of manufacture.

Altogether there are about 1,600 concerns in the United States manufacturing electrical equipment, most of them in only one or two specialized lines. Thus it is that there are opportunities in concerns of various sizes, and the question is often asked as to the relative advantages of small and large companies. Because of obvious exceptions to the rule, no final answer can be given to this question except in general terms. Each type of company offers different and varied opportunities and needs good engineers. Any one company also has many positions outside the strictly engineering field which can be filled to advantage by technical graduates. In general, it may be said that the electrical industry serves as a training ground for a large number of engineers who later go into associated fields, and that the opportunity for varied training is greater in the large company than in the small.

Products of the Industry

Let us look at the list of products that go to make up this 2.5 per cent of the nation's manufactures. The principal divisions are appliances, radio, refrigeration, industrial products, transmission supplies, wire and cable, and generation equipment. When these topics are considered in greater detail, a surprising variety is found. There are large and small steam turbines and generators for public utilities supplying light and power; there are transformers, switchgear, wire and cable, and insulators to carry the power to the consumers; there are motors of all kinds for industrial and domestic use; locomotives, streetcars, and subway trains for transportation; and a host of important apparatus such as mercury-arc rectifiers and electron tubes for power and control uses. There are lighting developments of all kinds both domestic and public, electrical testing equipment for innumerable applications, aids to medicine of increasing importance, and, of course, the many well-known appliances for the modern electrified home.

Rather obviously, except for the appliances, which play an increasingly important part, the products of the electrical manufacturing industry are for use by other industries. This means that there must be a close co-operation with these various industries. Application engineers spend their time learning the special needs of one or two industries, applying the proper available equipment to the present requirements of the industries, and translating the future developments into suggestions to the designing engineer. In the case of the sale of a large turbine and its accompanying generator to a public utility, the final delivery is usually the culmination of several years of co-operative work and study of the needs and peculiarities of the electrical system of which the generator will be a part.

Essentially full text of a chapter of a book "Engineering Opportunities," edited by R. W. Clyne of American Steel Foundries, Chicago, Ill.

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Engineering Staff

An industry having this array of products and supplying other industries so highly mechanized must necessarily have a fine staff of engineers if it is creditably to fill its place in the scheme of things. Out of the total number of wage earners in the electrical manufacturing industry (about 180,000 in 1935) the engineers numbered 3.3 per cent. This is a larger percentage of engineers than for any other industry except electric light and power, construction and maintenance of roads, miscellaneous mines, and radio broadcasting. This fact indicates the high degree of engineering supervision required because of the relatively custom-built nature of the products.

Clearly, such a large group of engineers needs to be continually replenished and augmented by new men with ideas. Approximately 25 per cent of the engineering graduates of the colleges of the country enter the electrical manufacturing industry. These new men, it must be emphasized, are not all electrical engineers. There is a great need for mechanical and other engineers, as well. The design of electrical equipment has many problems in mechanical engineering, involving stresses, heat flow, thermodynamics, and so on, so that a good engineer may have to become adept in almost any line of work. For example, an electrical-engineering graduate may eventually find himself wrestling with the intricacies of new developments in power generation by steam and binary systems or working in the development of new materials.

These figures are enough to show that the electrical manufacturing industry is one of the more important from the point of view of value of output; that a large proportion of the final value is added in the process of manufacture; that it is heavily staffed with engineers because of the nature of its products; and that it takes a large proportion of the engineering graduates of the colleges.

Development of the Industry

One of the most interesting studies in history is that concerning the growth of knowledge and use of electricity. The static phenomena of electricity have been known for hundreds of years. Nearly 200 years ago Benjamin Franklin experimented with lightning and Leyden jars, proposed the identity of lightning and electricity, and wondered how to put the then-existing knowledge to practical use. The phenomena remained principally a curiosity until Volta announced the discovery of a new source of electricity in 1800, and Faraday made his essential contribution—electromagnetic induction—in 1831. From then on electricity was subjected to an ever-more intense scrutiny by experimenters and mathematicians.

Only 50 or 60 years ago began the period of great application of electricity to the service of man. In the early '80's many things happened that encouraged the revolution in industrial life which the advent of electric power was to foster. The horsecar had been in service since 1860, and tracks covered nearly 4,000 miles. Transportation by this means already seemed slow and uncertain so that one of the incentives to develop a good electric motor was the need of improving streetcar service.

Important developments came thick and fast. Edison invented the electric lamp and in 1882 opened his Pearl Street generating station, making the worth-while contribution of the three-wire system. The American Institute of Electrical Engineers was formed. Stanley and others invented the transformer, allowing the transmission of power to greater distances than before. The polyphase a-c system was proposed by Tesla, who shortly invented the induction motor. (The possibilities of the induction motor were not realized for some years as there were troubles with polyphase systems and choice of frequency.) The search for new uses, better materials, and better methods led to the development of silicon steel by Hadfield in 1889. Lamme built a motor which has been the prototype of modern machines. Steinmetz unified the knowledge of alternating currents with his method of complex numbers, greatly simplifying calculations. The demand for better light in small quantities, impossible with the arc lamp, resulted in the development of the tungsten filament by Coolidge in 1906. The ever increasing demand for more power for lighting and industrial uses necessitated the development of the large steam turbine, the first one of which went into operation in Chicago only 35 years ago.

Contribution of Contemporary Industries

It is a modern theme of subtle importance that any economic movement of far-reaching effect must have a number of essential and underlying causes. Interpreting the

rise of the electrical industry in the light of this criterion, even a casual investigation reveals that in addition to the series of discoveries driven by intellectual curiosity and the excitement aroused by new uses of this new medium, contemporary industry must have provided considerable impetus. In other words, because of the urge to expand and the demand for better goods, the whole social framework was ripe for the very rapid expansion of the electrical industry through its ability to aid the other industries in their progress. The electrical industry grew whenever any other industry grew.

When Edison started his first central power plant in 1882, in New York City, he had a small steam engine and generator capable of supplying power for 400 lamps. Within a month he had trebled his capacity. This growth was prophetic of the electrical industry. In 1937 the central power plants of the United States had an installed capacity of 46 million horsepower, and were supplying nearly 27 million customers. As a further measure of this rapid growth, during the 20 years from 1910 to 1930 when the total number of engineers reported in the censuses was tripling, the electrical and mechanical engineers were gaining in relative importance as shown by the following percentages of the total:

	1910	1920	1930
Mechanical	16	28	24
Electrical	17	20	26

Much of this great gain in size and importance can be attributed directly to the influence of the various industries for whom electricity is an ideal servant. To pick only a single instance from the many cases of such industrial co-operation, consider the effect of the rise in the automobile industry. Directly affected were the steel, glass, machine tool, and rubber industries; indirectly, many others. Each of those in turn reacted on the electrical industry by demanding more motors and generators for mechanical drive, mine hoists, ship propulsion, machine tools, control equipment, lighting, and so on ad infinitum. The growth of one went hand-in-hand with the development of the other.

Recent technical progress in the electrical industry has been principally in the improvement and enlargement of existing types of apparatus. Hydrogen cooling has been used for large generators to allow the production of more power from the same volume of machine, small motors have been protected by built-in thermal overload switches to give more economical use of the motor's working ability, better vapor lamps and bigger electric locomotives have been built, better magnetic alloys have been developed. This continual and radical improvement in all lines is characteristic of the industry. Probably the greatest recent trend in the use of electricity has been the growth of home electrification, including its use on the farm. The net result has been a constant increase in the use of electricity in the home and in industry, requiring better and better engineering to produce better results for less money.

Characteristics of the Industry

One of the most important questions asked by engineering graduates, undergraduates, and prospective engineering students is "What kinds of engineers are needed by industry, and what do they do?" An even more fundamental question concerning any particular industry is, "What are its characteristics and how do these characteristics affect the type of engineers required?"

The fundamental element of the electrical industry—electricity—is exceedingly adaptable to the uses of mankind, but because of its impalpable substance and the nature of the laws it obeys, its economic application depends on the mastery of a great deal of higher mathematics, combined with careful training in the several branches of engineering. Fundamentally, then, this industry needs well-trained engineers.

In the second place, since the myriad uses of electricity involve a great many different kinds and sizes of apparatus—from the Boulder Dam generators to the small electric mixers for the kitchen—many different materials are required because of their special qualities—light, strong alloys, magnetic alloys, plastics, insulation, and so forth. Thus the industry needs engineers who are familiar with the technology and possibilities of these numerous materials.

The third important aspect of the industry is that its interdependence on other industries requires and contributes to the great number of new designs which are brought out each year by other manufacturers. The obsolescence of the driven machine is a powerful stimulus to progress in the electrical industry; greater, indeed, than that of newfound uses. For example, the advent of the continuous-strip steel mill necessitated the installation of some 25,000 to 40,000 horsepower in electric motors and generators. These were not new uses at all, but required many new designs and involved electrical, mechanical, and thermal problems.

It should be clear, then, that the industry needs a great number and variety of technical engineers—electrical, mechanical, chemical, metallurgical—as well as production, management, and sales engineers. This refutes the common notion that the electrical industry needs only electrical engineers. All of these engineers must eventually have a common outlook and uniformity of general ability not necessarily indicated by their engineering "labels," for their work is highly co-operative. This will become increasingly evident later in this article.

Types of Engineering

Any attempt to label and limit the types of engineering done in any one industry runs into this obvious difficulty: except on paper there is no exact demarcation. All engineers, salesmen, and managers must possess to some degree the abilities of engineering, salesmanship, and group planning. If titles must be chosen, the jobs which emphasize technical engineering are in research, development, design, and application; those emphasizing other abilities but also requiring engineering ability are in sales, management, and patent law.

Research

Research, as commonly thought of, is what is more strictly called scientific industrial research. This is done in a relatively small number of laboratories by men highly trained in physics and mathematics, who spend their time investigating the fundamental phenomena of our world in those lines where the information might be of subsequent value to engineering. A knowledge of the characteristics of arcs and electric discharges may lead to better circuit breakers, improved welding, more uses of electron tubes for control and power transmission. A study of the structure and properties of metals may lead to better steels, stronger magnetic alloys, and metals for special uses.

This type of research worker has been described in many articles and needs no further elaboration here. The work is not engineering in the strict sense of the word, for neither time nor money is a vital ingredient. But the work is essential to engineering progress.

The work of the men who carry forward the complicated analyses of electrical machines, who experiment with and calculate the performance of radically new designs of power plants using high-pressure steam, or mercury-steam cycles, and who plan better systems of control and co-ordination of the very complicated interconnected central power plants, might be called engineering research. These men are comparable to scientists in viewpoint and breadth of training, but they are connected very definitely with the engineering job of doing specific tasks better than before. They bear the burden of the pioneering engineering which must constantly digest the new-found facts of the scientist, advance the mathematical basis of the engineering involved, and, with the co-operation of many other men, begin the development of the machines that will mean material progress for all. This group is always rather small.

Development

The gulf between the suggestion of an idea and its emergence as a working device is bridged by the development engineer. Usually such an engineer is clever with his hands and is sufficiently imaginative so that difficulties may be foreseen and forestalled as the work proceeds, for there are numberless snags that must be worked out before a device can be manufactured to sell in profitable quantities. As an example of this type of work there is the development of a continuously indicating device for giving the torque and horsepower output of a marine turbine driving a ship's propeller. The idea is simple enough: two similar generators are fastened around the propeller shaft at a known distance apart and their output voltages connected in opposition. The magnitude of the net voltage will depend on the speed and the phase angle between the generator voltages (proportional to torque), thus representing horsepower. However, the difficulties of carrying out this idea are numerous. The mechanical construction is tricky because of close tolerances required by the electrical characteristics desired; the propeller shaft is not conveniently small; vibration and stresses must all be considered. The electrical design of the generators and indicating instruments is difficult because of the necessity for avoiding expensive equipment and maintaining reasonable accuracy. It is clear that the development engineer must not be restricted to electrical-engineering knowledge alone, but needs mechanical and thermal engineering as well as a knowledge of shop processes.

Design

Design is a much maligned word. It is quite probable that students in college have a poorer conception of this phase of engineering than they do of any other. Its connotation has grown to mean something like slaving at a drafting board, whereas the major task of the designer is to create a product that fits the desires of the customer as nearly as possible, can be built and sold at a profit, and embodies as many of the advantages of new materials, new methods, and improved appearance as possible. Whether the designer works at a drafting board or not, he is creating. His work with small apparatus may range all the way from the thoughtful combination of standard parts to fill slightly off-standard requirements, to the downright invention of a device to circumvent a baffling trouble. His duty at all times is to design a line of standard equipment that will fill as many conceivable demands as possible. When dealing with large apparatus or with any line that cannot be built and stocked as standard units, the designer has only past experience and his own calculations to guide him. Frequently new apparatus presents unforeseen difficulties.

From this it may be realized that a designer cannot be restricted to any one type of training. He must be able to analyze the electrical, mechanical, and thermal problems involved so that his own device may do its job, and so that it may fit in with whatever machine it must operate. Ease of manufacture and appearance of the finished product are often of great importance. The designer's knowledge need not be all-inclusive, but he has the responsibility for obtaining a good design wherever the information may be obtained. This indicates that a very broad and basic training and understanding is required. "Routine" is a word often associated with many jobs. No design job need be routine if it is realized what responsibilities and possibilities are open to those who are qualified.

The designers, in electrical apparatus manufacturing, constitute the largest group.

Application and Sales

The gap between designer and customer must be filled by one or both of the following men: application engineer and salesman. Clearly, the man who is to satisfy the wants of the customer must know the products of the designer. An application engineer functions chiefly in the apparatus field (supplies to industry) and has the duty of becoming intimately acquainted with the problems of one or several industries, thereby becoming almost a consultant for them. This group of engineers is small since comparatively few men are required to serve a large field. Such an engineer must be ready to decide impartially on the proper motor, generator, turbine, rectifier, or control device for any need that may arise. In doing this, he

works with the salesman handling the order or proposition. One of his more important jobs in relation to the manufacturing company for which he works is to help its designers keep abreast of the new developments in his industrial field. This type of work usually requires experience in one or more design departments and a considerable degree of association with the industry to be served. This association may be with the central station, industrial, or transportation fields.

Engineering is sometimes rather arbitrarily divided into two groups: technical and nontechnical. The types of engineers just described are classified as "technical," while such men as sales, advertising, and management engineers are "nontechnical." Both kinds of men must have similar talents, differing only in degree. The designer who does not know how to make his product easy to manufacture and sell, and who cannot convince others of these points, is in the same trouble as the salesman who does not understand and appreciate the technical excellence of his line.

Sales engineering consists of both advertising and actual sales work. These require emphasis on the special talents of salesmanship, handling of people, and fluent expression of ideas, both orally and in writing. However, in an industry producing machines involving as much engineering as electrical equipment does, it requires well-trained engineers to sell. Thus, first of all, the sales and advertising men must be engineers. Usually they are men who have begun with the rest of the engineering graduates, testing electrical equipment, possibly with one of the larger manufacturers, and have then had some experience in one of the engineering offices to provide a good knowledge of the equipment they are to sell. A salesman of this type does not do "house-to-house" selling. He becomes familiar with the users of his equipment in his territory, learns their problems, their plans, helps them decide on the material they need, makes sure the equipment really is fitted for the job it must do, and often follows it up to be sure that all is operating properly. A salesman to a power and light company will know the extent and power of its systems, the sizes and voltages of the power lines, the state and trends of the loads supplied by neighboring companies, and so forth. Possibly he will even observe the direction, strength, and intensity of lightning storms.

A salesman of small equipment knows what similar industries are doing so that he is ready to advise his customers intelligently. He must consider himself technically responsible for seeing that the customer gets what he needs, whether or not that is the equipment that was asked for. Customers in the electrical industry, as in any other stable industry, place repeat orders, and that means that good salesmanship must be combined with good engineering.

The advertising man promoting the sale of technical products usually works from the home office, and has duties similar to those of any other advertising man. He plans the campaign which will best help the district salesmen with the particular equipment they are selling. The distinguishing feature here is that, as before, the advertised product has been highly engineered and is sold to engineers, so that the responsibility of the advertising man is rather obvious—he, too, should have a good technical background. It goes almost without saying that the ability of expressing oneself clearly, accurately, and concisely (which must be a part of every engineer's training), is most highly developed and necessary in the advertising and sales engineers.

Home-Appliance Industry

In the preceding discussion it has been almost tacitly assumed that the equipment mentioned was power apparatus sold to other engineering industries as contrasted to home appliances which are sold more or less directly to the final user. What of the appliance part of the electrical industry? There the story is very similar, differing only in degree. The designers and development engineers must work in close co-operation with the distributors if the products are to be technically correct, economically possible, and soul-satisfying to engineer and housewife alike. This might be called a specialized field, but it must be emphasized that, along with the special and very necessary talents of advertising, sales promotion, market analysis, and psychology, there must be sound engineering.

Management Problems

More and more in industry and college there is mention of the engineering problems of management. The idea of scientific management is not a new one, but it is only within fairly recent time that the press of competition and the ever-increasing degree of engineering required for electrical equipment has forced careful planning and synchronizing of engineering, manufacturing, and selling. Management, of course, has to see that designers keep abreast of the field, that products are those that are being demanded, materials and workmen move along at a pace commensurate with the time limits set by the contracts, that expenses due to overhead, stocks, and production methods are kept down, that workmen are satisfied, and that the right men are in the right jobs. This sounds like a hodge-podge of duties, but there is always the simplifying principle that good engineering includes thoughtful planning—and again the basis for a good manager is a broad technical training so that no oversights nor hindrances may occur on the technical side. From then on it is a matter of engineering intelligence applied to the direction of men (actually much the more difficult of the two problems).

For example, consider management problems occurring in two diverse lines of manufacture, such as large turbines, and small control relays. Turbines, in general, are custom-built, vary from one another in any number of details, and take from six months to two years to produce, depending on the extent to which existing designs and material stocks may be used. The high degree of engineering required for a large turbine, where one-half of one per cent in efficiency may be a deciding factor in the purchase, necessitates the presence of a large and well-trained engineering staff, a large crew of experienced workmen, and all the necessary tools and materials. Management must

plan production over at least a two-year period—completely analyzing the design before construction is begun and increasing personnel and stocks to match the progress of the contracted work. In short, long-range planning to maintain a high degree of precision in a large machine is the keynote.

With the small control relays, on the contrary, management is concerned with a device that is manufactured in quantity. Competition is keen, so costs must be kept down, but the product must do the job well and cheaply. Whereas the turbine could be and had to be calculated completely and predicted because of the great unit cost, the relay may be partly calculated and partly developed experimentally. (The final degree of engineering is not so different in the two cases, but the amount per unit of production is very much greater for the turbine.) Designs must constantly be improved; new features, new materials, new methods must be used. Management is responsible for the integration of the combined efforts of engineering and manufacturing staffs to achieve these results. Great emphasis must be laid on the proper scheduling of work so that orders may be turned quickly into finished goods. When the relays are used in combinations (as for starting control of motors), then not only must the unit devices be accurate, but the composite equipment must work smoothly and well. In short, management must schedule both the engineering and production, synchronizing both to eliminate each bit of waste time and material in the interest of low cost.

The mere mention of the professions of patent law and field or service engineer should remind any doubtful person that many more types of jobs than have been discussed here require engineering as a basic training.

Engineering Problems

The products of an industry are as indicative of the engineering required as are descriptions of the various engineering jobs. The introduction to this article indicates the extent of the field, and further lists can be found in any handbook. In a field as broad as that of electrical manufacturing it is impossible to discuss all the varieties of products in any reasonable amount of space, so an attempt will be made to outline the engineering required for a representative product—a medium-sized general-purpose induction motor.

Such a motor must be part of a standard line of motors so designed that any one will supply all reasonable demands for torque and horsepower. Further, the number of motors in the line should be minimized without having to use much too big a motor for any one job. This requires careful proportioning of the entire line and sets close limits to the variation in size possible for any one motor. Each motor must deliver the specified torque and horsepower at the proper speed with good efficiency, good power factor, and low current drawn from the line, without exceeding a reasonable temperature rise.

Proportion and physical size limit the amount of material that can be used. For that reason it must be used to the best advantage. The design is a continual process of compromise and reconciliation of conflicting factors. The electrical characteristics themselves involve considerable adjustment between the amount of iron, the number of turns of wire in the coils, and the flux density. For example, to increase the torque requires more flux, which increases the heating and the no-load current and decreases the efficiency unless a larger motor is built. A motor must not only have good running conditions under load but must be well-behaved at no-load and starting. Often power companies limit the maximum starting current that may be drawn, in order to prevent excessive voltage-drop in the lines.

The electrical problems are difficult enough but there are mechanical and thermal problems as well. The motor must be light and strong, must have good bearings, resist vibration and not itself produce any. The windings must be fastened securely and must resist possible abuse and poor working conditions. Heat generated in different parts of the machine must be removed without allowing any part to get too hot, for the life of the motor is determined by its insulation, the life of which in turn is a critical function of the operating temperature. The motor must be quiet, particularly if it is to drive fans or air-conditioning equipment. The present trend for increasing the horsepower developed by a motor of a given frame size is intensifying the foregoing problems. Their successful solution requires the close co-operation of electrical, mechanical, chemical, thermal, acoustical, metallurgical, and production engineers.

Prerequisites in Training

This discussion of the kinds of engineering encountered in the electrical manufacturing industry emphasizes the fact that a good background in engineering is needed by all who have contact with engineering work. A broad but intensive fundamental training is preferable to specialization, because one must know something about many fields. Moreover, every company has special information that will have to be learned when needed.

Finally, it can hardly be emphasized too strongly that every type of engineer must be able to express his ideas fluently and forcibly, either in writing or by the spoken word. His ideas will be of little value unless transmitted intelligibly to other people. But first of all he must be a good engineer.

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Recent Developments in Electrical Units

By A. E. KENNELLY
HONORARY MEMBER AIEE

Actions have been taken recently by international bodies toward adoption in 1940 of new absolute unit standards for electrical quantities. A brief outline of the development of international standards and of the significance of the change are given in this article by an outstanding authority long active in this field.

IT IS proposed here to present a summary of the actions taken by the International Electrotechnical Commission advisory committee number 24 on electric and magnetic magnitudes and units (EMMU), June 23–24, 1938, in the plenary meeting at Torquay, Devonshire, England, with such brief historical outline as may enable electrical engineers who have not attempted to keep in touch with the development of the meter-kilogram-second (mks*) system to follow the most recent decisions.

The International Electrotechnical Comission

The IEC was brought into existence by a motion from the chamber of delegates to the International Electrical Congress of St. Louis in September 1904.[1] The work of organizing the IEC was promptly taken up by Colonel R. E. Crompton, who now in his ninety-fourth year is still living in England. It must be a great satisfaction to him to see how internationally important his IEC has become during his lifetime. The general secretary since the first meeting for organization held in London in 1906, has been C. LeMaistre, London, to whose invaluable services the IEC has been so greatly indebted. The present international president of the IEC is Professor L. Lombardi of Rome who not only was a member of the committee of the St. Louis congress which recommended the formation of the IEC but has remained an active supporter ever since and has done much notable work in preparing an international IEC vocabulary of some 2,000 technical terms, the first edition of which was accepted at Torquay.[2]

Twenty-seven nations now are affiliated with the work of the IEC, each nation maintaining a local national committee with its own officers. Plenary meetings of the IEC have been held in a number of cities of the world. The most recent, the ninth, was held at Torquay in June 1938. At these plenary meetings the international decisions on electrotechnical matters are formulated and adopted.

The work of the IEC is divided among some 25 advisory committees with their secretariats situated in different countries. The advisory committees agree to hold their own meetings about twice a year between plenary meetings; numerous such meetings have been held. A very large amount of international electrotechnical standardization has been satisfactorily effected by the IEC during its 33 years of existence, to the benefit of all countries. Even a brief summary of these actions would be too long to present at this time. Its actions are substantially unanimous. Those questions on which opinion appears to be divided are set aside until substantial unanimity can be secured. The IEC authorizes the convocation of International Electrical Congresses, the last of which, the eighth, was held at Paris in 1932 to mark the semicentennial anniversary of the first Congrès International des Electriciens in 1881. All the official actions of the IEC are published in two languages, English and French. Any third official language might be devastating in its effect as even the maintenance of two languages has been found to be very onerous to the institution.

Brief Historical Outline of the Giorgi MKS System

Professor G. Giorgi of Rome conceived and published the mks system in 1901. In 1904 he presented a paper on the subject to the International Electrical Congress of St. Louis.[3] He showed that by taking the *meter* instead of the *centimeter* as the unit of length, and the *kilogram* instead of the *gram* as the unit of mass, retaining the mean solar *second* as the unit of time, with an appropriate fourth fundamental unit, the centimeter-gram-second (cgs) system became converted into an absolute system including all of the practical electrical units thus far adopted, in simple one to one relationship, thereby eliminating the numerical factors 10^7, 10^8, 10^9, etc., which connect those practical units with their basic cgs units, thus simplifying the work of the electrical-engineering student. Thus a *kilogram* mass ($m = 1$),

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The author is indebted to the following persons for valuable suggestions and amendments: Doctor C. H. Sharp, president of the United States National Committee of the International Electrotechnical Commission; Doctor L. J. Briggs, director of the National Bureau of Standards, and members of his staff; C. LeMaistre, general secretary of the IEC; Professor L. Lombardi, president of the IEC; and M. A. Pérard, director of the International Bureau of Weights and Measures at Sèvres.

*In international usage, italic capital letters (*C.G.S.*, *M.K.S.*) are the accepted abbreviations for systems of units. This article has been modified to conform to American standard representations.

1. For all numbered references, see list at end of paper.

moving freely at a velocity ($v = 1$) of one *meter per second* relatively to its environment, possesses a kinetic energy, $mv^2/2$, of $^1/_2$ *joule* for the mks system just as a mass of one *gram* with the velocity of one *centimeter per second* has corresponding kinetic energy, $mv^2/2$, of $^1/_2$ *erg* for the cgs system.

The advantages of the mks system were recognized by the EMMU committee meeting of the IEC in 1930. At a meeting of the United States Committee of the International Physical Union (IPU) at Chicago in 1933, a resolution was passed favoring the adoption of the mks system. Later in 1933 the EMMU committee met at Paris and endorsed the Chicago IPU resolution referring the question of the mks system to the consideration of the various national committees of the IEC. In 1935 the IEC plenary meeting at Scheveningen-Brussels adopted the mks system without settling the question of "rationalization," appealing to the IPU and to the International Committee of Weights and Measures for an opinion as to the best fourth basic unit for the system.

IEC Plenary Meeting at Torquay in Relation to EMMU

Advisory Committee Number 24 of the IEC convened at Torquay on June 23–24, 1938. Torquay is hallowed to all electrotechnicians as being the residence for many years of Oliver Heaviside, the great master of applied mathematics. Fourteen countries were represented by delegates to the total number of 29 (Argentina, Australia, Czechoslovakia, Ecuador, France, Germany, Great Britain, Holland, Italy, Norway, Poland, Roumania, Switzerland, and the United States). The sessions were presided over by Doctor Clayton H. Sharp, president of the United States National Committee, the secretariat for the advisory committee number 24 being situated in the United States.

The following actions are quoted from the original minutes of the meetings:

1. The minutes of the preceding meeting of the committee held at Scheveningen-Brussels in 1935 were read and approved. At that meeting the IEC formally adopted the Giorgi MKS system without opposition, after the subject had been thoroughly discussed by the various national committees for several years.

2. The question of the rationalization of the MKS system was laid on the table and deferred for future consideration. There has been much difference of opinion in all countries as to whether the Giorgi MKS system should be rationalized or unrationalized. The decision turns upon the question whether the MKS unit of magnetomotive force should be the *ampere-turn* or the *ampere-turn*/4π. The same question had been purposely left unsettled at the Scheveningen-Brussels meeting of 1935 for fear of producing dissension detrimental to the general acceptance of the system if a vote were taken upon the matter at that time. It is hoped that in the course of a few years electrotechnical opinion may become crystallized upon the matter, permitting a nearly unanimous vote to be secured.

3. The committee, noting the concordant replies of Comité Consultatif d'Electricité and of the Symbols, Units, and Nomenclature (SUN) Committee of the International Union of Pure and Applied Physics as to the choice of a fourth unit in the Giorgi MKS system, agreed to recommend, as the connecting link between the electrical and mechanical units, the permeability of free space with the value of $\mu_0 = 10^{-7}$ in the unrationalized system or $\mu_0 = 4\pi \times 10^{-7}$ in the rationalized system. The committee recognizes that any one of the following practical units, *ohm*, *ampere*, *volt*, *henry*, *farad*, *coulomb*, *weber* already in use may equally serve as the fourth fundamental unit, because it is possible to derive each unit and its dimensions from any four others mutually independent. (Note: The necessity for high accuracy has usually led the national laboratories to base the realization of the absolute units on determinations of the absolute *ohm* and the absolute *ampere*. For purposes of technical measurements, however, the practical standards are generally those of resistance and electromotive force as they have the advantages of portability, simplicity, and accuracy in use. Standards of these two quantities are maintained by the Bureau International des Poids et Mesures at Sèvres.)

4. The committee voted upon the question, appearing in the agenda, of adopting the name *newton* for the unit of force of the Giorgi MKS system, (10^5 *dynes* in the CGS system or roughly the weight of one *hectogram* of matter, or more nearly 102 grams, at sea level). The vote was ten to three in favor of the motion, with one country abstaining, subject to confirmation by the various national committees under the six-months rule. The ten accepting countries were Australia, Czechoslovakia, Ecuador, France, Great Britain, Holland, Poland, Roumania, Switzerland, and the United States.

5. It was voted that the name of the system should be the Giorgi (MKS) system and Professor Giorgi, who was present as an Italian delegate, was requested to prepare a further memorandum explanatory of the use of his system.

The preceding resolutions were forwarded to the committee of action of the IEC and formally accepted in plenary meeting. For further particulars the reader is referred to the forthcoming official minutes of the IEC Torquay meeting as appearing in the French and English texts.[4]

International Committee of Weights and Measures at Sèvres

By an amendment to the Convention of the Meter formulated at the General Conference on Weights and Measures of 1921, authority over electrical units was assigned to that conference and its subordinate organizations, the International Committee and International Bureau of Weights and Measures. The Weights and Measures Conference acting on reports from the various national physical laboratories decided that the specifications for the international standard *ohm*, *volt*, *ampere*, etc., set up by the Chicago congress of 1893 and elaborated by the London conference of 1908,[5] had not met international requirements to the degree of precision desired. It directed the International Committee of Weights and Measures to set aside the "international" standard series and specifications in favor of new standards based upon new absolute measurements of the absolute practical units embodied in wire resistance coils of improved construction and improved standard Weston cells, made by the national physical laboratories. Copies of these new "absolute" standards are to be deposited at Sèvres so as to permit of ready intercomparison. It had been found that the "international" *ohm* and "international" *volt* prepared in the national laboratories of any one country according to the specifications of 1893 and 1908 differed slightly and were also subject to small but distinct changes with time so that the "international" *ohm* of one country

might differ from the "international" *ohm* of other countries by amounts considerably in excess of the observational errors of comparison.[6,7] The countries taking part in the production of the standards of the absolute practical units were France, Germany, Great Britain, Japan, Union of Soviet Socialist Republics, and the United States.

The International Conference of Weights and Measures is required by treaty to meet in Paris, ordinarily at regular intervals of six years, so that its next meeting is projected for 1939. The International Committee on Weights and Measures, the president of which is the well-known scientist Professor V. Volterra of Rome, meets every two years at the International Bureau of Weights and Measures at Sèvres. The Bureau under the direction of M. A. Pérard maintains the prototype standards of length and mass—the international *meter* and international *kilogram*. It is ultimately proposed to maintain also at the Bureau standards of the practical absolute electrical units based upon the values of the standards from the national laboratories as well as international standards in photometry and thermometry.

In 1935 the International Committee of Weights and Measures with the aid of its Comité Consultatif d'Electricité issued a table of probable ratios between the "international" and the corresponding "absolute" units, to four decimal places (see table I).[8]

It was recommended by the international committee that the new absolute units at Sèvres should go into effect on January 1, 1940, also that the pre-existing standards in various countries should not be altered but that the new standards after January 1, 1940, should conform to the finally established mean ratios. At its meeting in 1937 the international committee announced the revised provisional ratios carried to five decimal places, obtained up to that date from the national physical laboratories, as follows:[9]

one international mean ohm = 1.00048 absolute ohm
one international mean volt = 1.00036 absolute volt

From these it may be inferred that the mean international ampere is 0.99988 absolute ampere and similarly the ratios for the other electrical standards are derivable. Not all of the co-operating national laboratories had completed their comparisons at the date of the 1937 meeting so that the above ratios to five decimal places are not yet final.

It has been supposed by some that the mks system could not be employed until the standards fixed upon at Sèvres had been put into effect in 1940, but it is evident that the actions to be taken by the International Committee of Weights and Measures do not affect the theory or application of the Giorgi mks system but only the international standards of the absolute units to be maintained at Sèvres. The mks system is now ready for use by students and writers, after they have decided whether in electromagnetics their units shall be rationalized or unrationalized. A corresponding choice, in this respect, has also to be made by those who use the cgs units. Textbooks are in course of publication for illustrating the use of the mks system to students and articles upon the elementary application of the system will no doubt appear in technical journals from time to time in the near future.

The original British Association for the Advancement of Science (BA) *ohm* adopted provisionally at the Paris congress of 1881 represented the resistance under standard specifications of a uniform column of mercury approximately 104.8 centimeters in length. Following the commission's report of 1884 the BA *ohm* was replaced by a new ohm called the *legal ohm* of approximately 106.0 centimeters, an increase of more than one per cent. By

Table I

International	Absolute
Ampere	0.999 9
Coulomb	0.999 9
Ohm	1.000 5
Volt	1.000 4
Henry	1.000 5
Farad	0.999 5
Weber	1.000 4
Watt	1.000 3
Joule	1.000 3

the action of the Chicago congress of 1893 the *legal ohm* was replaced by the *international ohm* of approximately 106.3 centimeters, representing an increase of about one-quarter of one per cent. Under direction of the International Conference of Weights and Measures the *absolute practical ohm* in the form of standard coils is expected to correspond approximately to 106.25 centimeters, a reduction of about 0.05 per cent or in the ratio 1/1.0005. The corrections to be made in the other electrical standards are all smaller than those in the standard *ohm* with the exception of the *farad* and *henry* whose corrections are the same as for the *ohm*.

The readjustment of the electrical units effected in 1885 and 1894 did not give rise to any serious amount of confusion or misunderstanding. The corrections due to be made in 1940 will be insignificant from the standpoint of ordinary electrotechnics but in electrophysics will need to be taken into account by numerical coefficients when accurate measurements are required.

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Management's Responsibilities to Society

By A. W. ROBERTSON
ASSOCIATE AIEE

Society often has decreed regulations and restrictions that hamper management and private enterprise; but society is the sole arbitrator of what it considers right, and management must conform, says this chairman of the board of a leading electrical manufacturing company. He emphasizes the vital importance of private enterprise in modern life and the dependence of successful private enterprise upon good management.

MANAGEMENT is to be found everywhere. In our homes, in our personal affairs, in our factories, and generally throughout all social functions; economical, political, or otherwise. And if a thing is thought to be devoid of management someone is always popping up to inject a little management into it, such as making a managed currency or a wheat crop or managing the supply of cotton, the number of pigs, and everything in general. Unfortunately, the various efforts of management do not always harmonize. In fact, more often than not the efforts of different managements are in conflict with each other so that if one management succeeds, the other must necessarily fail. The hunter of seals is directing all his managerial ability to killing seals. Government may be devoting all its managerial ability to keeping the seals alive.

Management has been in existence as long as civilization. But in the present age management controls larger groups than in any other age. It is only during the last fifty years that we have seen organizations of national and international scope. Today we think of management as the organizing force in the world of affairs. It is the *know how* of business and industry. It is concerned with order, discipline and accomplishment, and is against disorder and inertia.

Practical Definition for Management

Management uses the intelligence, labor, and wealth of man with the materials and forces of nature to produce things or services which other men want. It is absurd, in a sense, to define management to you, but in another sense it is a wise precaution to insure our common approach to the subject. Management is the last and best means by which man, the builder and creator, takes the manifold riches of nature which, in their raw or natural state, are useless to him and molds them to his needs. The distinction between the work of management and the work of an individual is that the results of management's activities are always for others. To survive, management must produce what others want, whereas the individual more often than not, is concerned with producing what he alone wants. The multifarious activities of management are beyond description, and some of the activities might be called mismanagement.

Management is necessary to sell a steam boat or a Fuller brush; to run a hat-checking concession or an automobile factory; to operate the Pennsylvania Railroad or a beauty parlor; to give a picnic or conduct a funeral.

Management will function in Europe or Africa, but it prefers civilized communities. The higher the standard of living, the better management functions. Or restated, the better management functions, the higher the standard of living.

Our attention is directed to that part of management which has to do with private enterprise.

Management enables man to advance through the helpful co-operation of other men. Alone he is pitiful. At best he is little more than an animal, and no matter how brilliant he may be he cannot rise far without the help of others. He is born naked and helpless. He travels but a short distance and is tired. His strength wanes unless he is fed. He may know much, but the wisest man has explored only a little bay on the shores of the great ocean of knowledge. Only in the union of minds under capable management does he become supreme. Management unites individuals in effective co-operation. The corporation is the modern vehicle for this purpose. Through it the widow's mite aids the laborer to produce what the consumer wants. Management acts as steward and trustee for all—investor, laborer, and consumer. The results are astonishing. The laborer has received the highest wages for the shortest hours. He has at last found leisure and has become a consumer. He now knows comfort and has luxury. He is unable to appraise his condition as there is nothing in all history with which to compare it. This is true even though there are 10,000,000 persons unemployed in the United States. The unemployed today is better off than was his brother of former ages when employed.

The consumer has been furnished with goods and services which have added to his bodily comfort, relieved him of work and worry, lengthened his life, and benefited him generally. The investor has found management enterprises a safe place in which to invest his funds with profit, not only to himself but to the world at large. The

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securities of private enterprise are the backbone of our insurance companies, investment trusts, and the private wealth of our citizens. However, notwithstanding his present-day luxuries, man still feels naked to the world and longs for security. Although his environment has changed, he has not changed.

Management Must Be Alert to Change

Management has no right of way. It thrives or languishes at man's decree. It has a difficult task. It must be alert to an ever-changing world and must change with the times. Unless it succeeds in doing this, a private enterprise must fail. It must therefore have freedom to try new ways and improve old ways. Any restrictions which destroy its initiative will ultimately destroy it. Here lies the great threat of government against management. Government is the great enemy of initiative. Its chief duty is to make rules and regulations, and every rule is a curb on freedom and danger lies in making everything and everyone conform to a type.

At the present time, government everywhere is endeavoring to force all men to be equal by restraining the strong and assisting the weak. All fair-minded persons will agree that there are times when the strong should be curbed and the weak should be aided, but it is obvious that restraint checks initiative and too much supervision destroys it, whereupon all true management activity ceases.

The world is founded on faith and integrity. The goods and services of management are accepted generally upon their face value. I trust the men who make the automobile I buy, and I do not know any of the thousands who have contributed to the finished product. When I step into an airplane I trust my life to the organization which built it and to the pilot who operates it. When I receive a telegram I do not question the integrity of the message.

Management must be honest, capable, and wise, even as you and I, and its goods and services must be worthy of highest trust; but it must also accept the task of leadership in the conquest of our natural world. Man must combine his forces to win. Nature is relentless. It will reclaim every secret and recapture every stronghold our age has won unless we are alert to hold it and press on to new victories. It is pleasant to be complacent, but other civilizations as proud as our own have gone down leaving only broken fragments to tell the story of their glory. Through wise management of our abilities and resources we have advanced far beyond any previous frontier, but what we have gained can be lost. And it will be lost, and retreat will be inevitable if the attack against business succeeds in curbing management and killing initiative.

Management has served best in free countries. The United States has been ideal for its development. Here the best talent is drafted from 50,000,000 workers. The managerial type of person is rare. It is not enough to be intelligent, industrious, and trustworthy. The management of a great modern enterprise must have special courage, unusual foresight, and a knowledge of psychology and human conduct beyond mere book knowledge. The necessary co-ordination and co-operation of thousands of different individuals, all alien of end and of aim, so that their diversified talents and knowledge are harmoniously directed to accomplish a definite thing is no small task. Teamwork is what does it.

It is easy to get co-operation, but more difficult to get co-ordination. August Bruski had a wife and a bright boy of fourteen and an older daughter. The peace of the little family was almost wrecked over their willingness to co-operate and their failure to co-ordinate their efforts. The son won a place on the commencement program of his school. He knew his speech perfectly. The family was proud and happy until the night before the great day, when the family decided that the boy had no suitable clothes unless he could wear his father's trousers, which were six inches too long. The father wasn't willing to have the six inches cut off and the son was in tears at the thought of wearing them rolled up. However, it was decided, after long debate, that that was the best thing to do, and the family retired—but not to sleep. The mother shared the horror of her son at the thought of those rolled-up trousers and at last decided to get up and cut off the extra six inches, which she did. Meanwhile, the sister tossed and fretted in sympathy with her brother and finally she too decided to cut off the extra six inches in an effort to co-operate. So she got up and cut another six inches off the trousers. Co-operation without co-ordination will not make our pants fit.

Plato's Rules and Good Management

Good management is the rule of the best minds. Organizations controlled by management follow the rules laid down by Plato for the perfect society, namely, "the wisest have the most authority." It is antidemocratic, although private organizations flourish best in democratic countries. However, the democratic rule of the majority will frustrate and defeat any management. The crew cannot run the ship. It is popular to think that the majority is always right, but there is as much difference in feeling right and being right as there is in feeling good and being good.

A friend was crossing one of the many bridges which span the Allegheny River in downtown Pittsburgh, when he was stopped by two robbers who demanded his pocketbook. My friend protested. The robbers replied that they wanted only what was right and fair and would be willing to submit the matter to a vote of the three of them and let the majority decide. With all solemnity the vote was taken and the majority won and my friend lost his pocketbook.

Decisions in organizations under management are never made by weight of numbers. Every decision is made by those persons best qualified by knowledge to make it. Finally, all decisions of each qualified group or division are co-ordinated into the activity of the organization as a whole.

Management is impersonal. It must travel a narrow road. The twilight zone of human frailties and error, which bounds all our acts as individuals, is denied it. Management may be kind, but not sentimental; liberal,

not extravagant; frugal, not stingy. Higher things are demanded of management than we require of ourselves.

The ordinary results of management—trains on time; complete machines, such as automobiles, that operate perfectly; a plentiful supply of daily food; all these illustrate better than anything else how far we have traveled from the disorganized, confused world of other days. Athens fought Sparta and both were ruined because they had no means of communication except on foot. The two cities were strangers. Today, London and Berlin are not strangers; neither are New York and Los Angeles. Due to modern means of communication these cities are in constant touch and the traveler can visit either with greater ease and comfort than a citizen of Sparta could go to Athens, 100 miles away.

In the States we speak of George Washington, our first president, as the father of our country. Our great progenitor was the father of a little country on the Atlantic seacoast. If the facilities of communication, to mention only one modern convenience, had remained as they were then, the United States of America as we know it could not have existed. The people of the Middle West would have been foreigners to the East, and the Pacific Coast would have been a separate empire beyond the Rockies—vague, mysterious, and unknown—visited only occasionally by a few courageous travelers who enjoyed hardship and danger. This inevitable condition was prevented because private enterprise furnished the telegraph and telephone for speech communication and the railroads for transportation of goods and persons. The grain of the great plains could find a market in the East. We developed a need for each other. It might well be that Alexander Bell, with his telephone, or George Westinghouse, with his air brake, might likewise be called fathers of our country. George Washington started it, but it could not have been developed to its present state without countless contributions from private organizations.

We are so accustomed to the luxuries and conveniences of our modern life that we no longer value them or view them as the miracles they were once thought to be. Everything is accepted as a matter of course. If we could look through the eyes of our forefathers we would see these everyday things differently. Let us ask an old forty-niner, who crossed the continent with an ox team averaging eight miles a day, to inspect and ride on the new "Super Chief" that leaves Chicago at 7:15 p.m. and 39 hours later rolls into Los Angeles. What he would feel and say would gladden the heart of every railroader and do much to restore his confidence in his profession.

Why not bring Columbus back to life and take him on a tour of inspection of the "Queen Mary?" No phrase fits his astonishment except to say he would not believe his eyes. "Such a monster could not float! And what could make it move? It has no sails." His astonishment and bewilderment would be complete if in less than 5 days he traveled over the very ocean which he so laboriously crossed in 70 days.

I cannot resist inviting Sir Isaac Newton, the great scientist, to tour our modern research laboratories, all a part of management's contribution to society. He would find that science had learned secrets of nature which would make even the law of gravitation commonplace. And in addition to learning the laws of nature we have also learned how to apply them in endless ways, not only for the glory of God as the old order said, but for the use and comfort of man himself.

Management of a private enterprise must not only produce goods and services, but must make a profit, or it fails. All managers know this and accept the responsibility of making profits as a spur to wise administration. Management knows it is on the fairway if its operations are in the black. Profit, or the lack of profit, is the one thing which insures efficiency in private enterprise as contrasted to an activity without the profit motive. But because of profits, management is charged with being greedy. It is easy for the "have nots" to cry, "Shame!" To be specific, it is alleged that too much money is earned in private enterprise and paid out to the owners or stockholders, and that managers themselves get too large a share in salaries and bonuses.

Let us examine the first charge, that private enterprise makes excessive profits. It is interesting to note that this charge is made now and not when the fortunes of the Vanderbilts, Carnegies, Harrimans, Astors, and Rockefellers were made. It is obvious that great profits have at times resulted from private enterprise, but the average net earnings of 200 major companies in America during the past ten years were less than six per cent on the investment. During that period, exceptional companies did make large profits, but other exceptional companies had great losses. The conspicuously successful company receives all our attention and the world carelessly assumes the exception proves the rule. When the public thinks of an automobile company it thinks of Ford, General Motors, Chrysler, and a few others that have been very successful, and forgets the scores of other companies such as Winton, Stutz, Mitchell, Peerless, and Mercedes, which not only did not make profits but actually failed with the loss of all on board.

Over any long period of time the failures in business practically equal the successes. Dun and Bradstreet reports that every day on an average of 1,292 new corporations are created, and 1,142 come to an end by one means or another. The record of management not only shows no exorbitant profits on the whole, but actually shows extreme and fatal losses, which in many cases might be laid directly to mismanagement. Management might properly be taken to task for making too little money, not too much. The profits are so small, as a rule, that I am surprised the stockholders do not form a union to demand a greater return. Perhaps they need only a John L. Lewis to arouse them. In any case, a lucrative reward awaits some enterprising person as president of the International Stockholders Protective Union. The ISPU might serve a useful purpose by presenting comprehensive demands for a greater share of the income of business to offset insistent demands of other groups. No, management is not guilty of exorbitant profits.

Turning for a moment to the charge of too-high salaries and bonuses, it is not easy to know what management

should be paid. It is significant that high salaries are not paid for long to poor management because management must make its own salary and bonus. In America taxes reduce high salaries and bonuses very sharply. As one high-salaried man said: "The government is more interested in my salary than I am, as the government gets most of it."

What are the services of anyone worth? I assume that all other little girls nine years old would say that Shirley Temple is overpaid and that they would gladly take her place for much less.

It should be borne in mind that in this age management does not, as a rule, own the business it manages. It is hired by the owners to run the enterprise and is usually paid enough to keep it from going to some other organization or starting a competing business. Whether it is too much or too little would depend upon the circumstances, but I do know that the salaries of top management in the average company are less than one per cent of the payroll, and who would not pay this much for good management? For that one per cent of the payroll the enterprise is successful and the consumer gets the goods he wants, labor is employed, and the owners are recompensed.

The most recent charge against private enterprise is that it is responsible for unemployment because it hasn't work for all. Government says to industry, "You must employ more labor or else." It is about as foolish as though someone would tell each one of us, "Before you leave Washington you must buy an automobile and hire a chauffeur for a year and take both to your home and use them." And when we refuse to do so charge us with being responsible for unemployment. Generally speaking, the whole charge is grossly unfair. Private enterprise is engaged in providing goods and services for others in a highly competitive market. If the public or consumer wants the goods and services and buys them, then business has need for labor and can give employment, but unless it can sell its products first it cannot give employment. The perfect example of this is the electric service utility. Unless a customer (multiplied by thousands) presses a button or closes a switch the utility makes no sale and has no output, and no income. The utility, of course, cannot produce goods or services that its customers do not voluntarily accept. Other industries, whose products can be stored in the absence of consumer demand, are stopped just as definitely, however, by limits imposed by financial resources, by storage space, or by depreciation of the product. The confusion of thought on this simple point is amazing. It reminds one of the two inmates in the insane asylum who were engaged in driving, or trying to drive, a common nail into the wall of the room. The first man held the head of the nail against the wall and tried to drive it in, without result. He was heard to exclaim in disgust, "The darn fool's put the head on the wrong end." The other inmate said, "You ought to drive it in the opposite wall."

There is a general belief that management will not hire people over 45 years of age. This is pure myth. Well-established factories with which I am familiar have a higher percentage of their employees between the ages of 45 and 68 than the whole population of the United States has between these same ages. This is also true if you take for comparison ages 40 to 68, or 50 to 68. Every organization values its trained and dependable older men and, in times of depression, keeps them to the last. Competent older men always have whatever work there is. If any group has a just complaint it is the younger men, who are always discharged first.

It is true that the older man out of work has a harder time getting a job because industry always has a full crew of older men, as we have shown, and needs to hire younger men to get their point of view and to train them to be useful older men some day. Pitiful as the case of the older unemployed may be, it is tempered materially by the fact that he is preferred in the job when he has one.

Management has a great responsibility to furnish as regular and remunerative employment as it is possible to do. Under modern conditions, the average employee hopes and expects to work for a good organization all his life. He marries, buys a home, and makes commitments for the future, all based on his expectations of continuous employment. This is a perfectly natural thing to do, and management must recognize that it has the responsibility to meet the expectations of its employees, if at all possible. In the past, management has paid scant heed to the problem of furnishing yearly employment. It has expected labor to share the ups and downs of business. If times were bad labor was unemployed. In a degree, this cannot be avoided. But management, by careful planning, may be able to smooth out, to an appreciable extent, the ups and downs of labor. Management has been guilty of a day-to-day existence, which magnifies the plight of labor. If management holds out the hope of employment today, it must not shatter that hope tomorrow. Management should be able to plan its work so that improvements, major repairs, and expansion are done in periods of depression when labor might otherwise be unemployed. This means that private enterprise must have sufficient funds to carry it through depressions with confidence. Government must assist management in this laudable undertaking and should be interested in assisting it to maintain a sound financial condition rather than weakening it by unwise taxation.

The modern world is complicated beyond belief. No one, not even the simplest citizen, lives what might be called the simple life. None of us can truly take care of himself. We depend entirely upon other people for the necessities and luxuries of our lives. Light comes to us over a wire; heat through a pipe; water through another pipe. We are carried to and from our work in public conveyances. Food is to be found around the corner if we can get the necessary nickels to purchase it, and if we cannot, government has to furnish it or we perish. In such a world the need of management is imperative. The minute the mob takes over the power plant the city is in darkness. Order and system, which are possible only through management, must prevail throughout the modern world. The managers of today, imperfect men as they are, are still the pick of all the candidates available, and it is their responsibility to maintain the proper functioning

of the vital necessities of our life. Management may not quit under criticism. It is not enough to stand up under criticism when one merits it, it is necessary to stand up and take it on the chin when one does not merit it. This is the law of good sportsmanship. It is also the law of good society, and management must measure up to it. If anyone is captain of our modern ship, management is, and it cannot desert its post.

The collateral responsibilities of management are many. Large factories and mass production lead to congested living conditions and the inevitable lowering of health and morals. Management is not directly responsible for the social conditions which are the indirect result of its factories and production methods, but it must nevertheless accept a fair share of the responsibility for these indirect results. The rise of material well-being, which is everywhere apparent, was attained only at a price. The innocent victims of these conditions are helpless. They are the weak and the unfortunate and in every age suffered ill health and have been poorly fed and poorly clad. But their condition, by proper attention, may be ameliorated and management must accept part of the responsibility for the amelioration. Just as it has long since accepted the responsibility of securing safe and healthful surroundings in which men work, it must now accept the responsibility of helping employees secure safe and healthful surroundings in which to live. Anything short of this is a neglect of clear responsibility.

Since we live in an almost wholly artificial world, there would seem to be no escape from providing artificial or man-made aids to health. Parks and playgrounds must be furnished and a reasonable amount of outdoor life provided. The comfort and health of every community must receive constant attention.

Finally, since management can exist only in an environment suitable to its needs, it must recognize its obligation to the society of which it is a part. In many cases society has decreed regulations and restrictions which hamper management and private enterprise, but society is the sole arbitrator of what it considers right, and management must conform. It has no choice. It is as helpless in the face of social restrictions as it is in the face of economic conditions. All management of private enterprise realizes that changing times affect business and may in time render it useless. The canal has gone. The horse and buggy has gone. The street railway and steam railroads are suffering from changed conditions, but management must accept these things and it must also accept proper governmental regulations.

And inasmuch as government is forced by the very nature of things to assume a larger and larger role in our everyday life, regulating more and more what we do and how we live, it needs the assistance of management more than the government of any other age. Management should willingly offer its talents and services to government because management is the only source from which government can get the necessary talent to operate its many activities efficiently. It now ignores management, and management scowls at government. They are both wrong. Meanwhile the people suffer. Modern government cannot exist without better management. Management must accept its responsibilities and offer its services to any good government that asks for them. Government has a proper field of regulation which management recognizes and accepts. It is equally true that management has a field of accomplishment which government now lacks and would do well to recognize.

Complexities of This Kilowatt-Hour Age

The affairs of man move along with surprising speed and power. We see trade and commerce going on uninterruptedly between individuals and between groups of individuals, with ships crossing every sea and stopping at every port. It is obvious that a well-ordered world is necessary for the growth of prosperity and that anything which interferes with the exchange of raw materials or the products of human labor tends to lower the standard of living, but it is not obvious that private enterprise is the mainspring of all our activities. The demagogue ignores private enterprise and considers it of no importance. The situation reminds me of my experience the other day in an airplane. I was sitting forward and looked out the window from time to time. Nothing but the wing obstructed my view. I could see the whole horizon and the ground below at an angle, I repeat, nothing obstructed my view; I could see clearly. I was alarmed when I realized that my view was directly across the end of the motor where there should be a propeller. But there was none. I mean I couldn't *see* one, and as far as my eyes were concerned there was no propeller. If I had not known that I couldn't see a fast-moving propeller, I might have assumed that airplanes move through the air by virtue of government regulations, or some mysterious power, without propellers. Sometimes I think we judge our civilization just as faultily. We see things moving along, goods being made, wages being paid, taxes being collected, human beings living and dying with a more or less steady rhythm, and we haven't any idea of what keeps things moving. We can't see the propellers of our civilization. The greater the speed of living, or the higher the standard of living, the less people comprehend it. Almost anyone can understand a horsepower civilization and the simple transactions which constitute its life. Grain is planted, harvested, and sold; simple goods are manufactured and purchased. The complete round of life is clearly visible. But who among us can get a glimpse of the mechanism of this kilowatt-hour age, which is propelled through space almost as fast as the electric current which symbolizes it? Propellers we cannot see may be overlooked and neglected.

Under such circumstances, when the wisest are at a loss, and it seems easier to be wrong than to be right, management must stand by its colors, struggling to maintain the cause of free enterprise in a world threatened with unwise regulation. Free enterprise may confidently hold up its head as representative of one of the most vital functions in our national economy today. It is the one thing which stands between us and a stale, flat, unhappy world of universal regimentation and individual conformity to a single pattern.

News

Of Institute and Related Activities

North Eastern District to Meet at Springfield

A three-day meeting and Student Branch convention of the AIEE North Eastern District will be held May 3–5, 1939, at Springfield, Mass., under the sponsorship of the Springfield Section. Headquarters will be at the Hotel Kimball, and arrangements have been made to house those attending in this hotel and in other hotels in the city.

Springfield, situated in the Connecticut River valley, is the center of a growing and prosperous industrial area, and is convenient for those traveling by automobile. Excellent transportation facilities are also available from all points to Springfield by either bus or railroad.

An attractive program of entertainment, sports, inspection trips, and technical sessions will be offered. According to present plans there will be four technical sessions, one general session, and two student sessions; the latter will run concurrently. Many high-grade papers are available for the technical sessions, which will be of interest to different groups of engineers, and there will be addresses of interest to all attending the general session. Present plans contemplate holding the two student sessions Friday morning, May 5.

A stag smoker will be held Wednesday evening, May 3, at the Highland Hotel. Plans are being made to provide interesting entertainment and a buffet luncheon will be served. An informal banquet will be held Thursday evening.

W. O. Henschke (A'32) present chairman of the Section, is general chairman of the committees on arrangements for the meeting, and F. R. Longley (A'25) is chairman of the meetings and papers committee.

Hoover Medal Awarded to J. F. Stevens

John Frank Stevens, 85-year-old civil engineer of Baltimore, Md., was presented with the third Hoover Medal during the recent meeting of the American Society of Civil Engineers in New York, N. Y., with the following citation:

John Frank Stevens, engineer of great achievement as illustrated in his work on the Panama Canal, who, in his dealings with the Inter-Allied Forces in Siberia in the Great War, demonstrated those broader capacities for humanitarian public service beyond his calling, which have earned for him the recognition of the Hoover Medal for 1938.

Born in West Gardiner, Maine, April 24, 1853, Mr. Stevens, after serving as assistant engineer of the City of Minneapolis from 1874 to 1876, engaged in engineering service on railroads in the Northwest, until in 1905 he was appointed chief engineer of the Panama Canal, and later chairman of the Isthmian Canal Commission. From 1907 to 1909 he was vice-president in charge of operations of the New York, New Haven and Hartford Railroad, and later became president of several West Coast railroads. He went to Siberia in 1917 as chairman of the Commission of Railway Experts to assist the Russian Provisional Government in the reorganization and operation of its railways. Following the Armistice he remained in Manchuria and became president of the Inter-Allied Technical Board. In 1927 Mr. Stevens was elected president of the American Society of Civil Engineers, and he has been awarded the John Fritz Medal, the Gold Medal of the Franklin Institute, and other honors.

The Hoover Medal was formally instituted in 1930, to commemorate the civic and humanitarian achievements of Herbert Hoover (HM'29) to whom the first award was made. The second award was made to the late Ambrose Swasey in 1936. The board of Award consists of representatives of the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the AIEE. Present chairman of the board of award is Gano Dunn (A'91, F'12) president of the J. G. White Engineering Corporation, New York, N. Y., and AIEE past-president.

Alfred Noble Prize for 1938 Awarded

Announcement has been made of the selection of Ralph J. Schilthuis as winner of the Alfred Noble Prize for 1938 for his paper, "Connate Water in Oil and Gas Sands," published in the 1938 issue of *Petroleum Technology*. Mr. Schilthuis, who is in the production research department of the Humble Oil and Refining Company, Houston, Texas, will receive the prize at the annual dinner in February 1939 of the American Institute of Mining and Metallurgical Engineers, of which he is a member. He has been employed by the Humble company since his graduation in 1930 from the Colorado School of Mines.

The recipient of the Alfred Noble Prize is selected by a committee of five, consisting of one representative from each of the four Founder Societies and the Western Society of Engineers. The prize was instituted in 1929 in honor of Alfred Noble, past-president of the American Society of Civil Engineers and of the Western Society of Engineers, and consists of a $500 cash award and an engraved certificate. The award is made to a member of one of the societies represented for a technical paper of particular merit accepted by the publication committee of any of the societies for publication in whole or in abstract in any of their respective publications, provided the author is not over 30 years of age at the time of acceptance of the paper in practically its final form. The award now is made for papers presented during the 12 months preceding June 1 of each year. The present award is the sixth, the first having been made in 1931; three have gone to members of the AIEE.

This year, for the first time since the establishment of the prize, an honorable mention was given. This went to E. C. Huge of Barberton, Ohio, for his paper entitled "Experimental Investigation of Effects of Equipment Size on Convection Heat Transfer and Flow Resistance in Cross Flow of Gases Over Tube Banks." Mr. Huge is a member of The American Society of Mechanical Engineers.

D. W. Mead to Receive 1939 Washington Award

Daniel Webster Mead (A '11, F '13) has been elected to receive the Washington Award for 1939 "for his superior contribution to sound theory, good practice, and high ethical standards in the creation of engineering works as an engineer and as a teacher," according to an announcement by the Washington Award Commission. Doctor Mead is a consulting engineer and professor emeritus of hydraulic and sanitary engineering at the University of Wisconsin, Madison. A biographical sketch of Doctor Mead may be found in the "Personal Items" section of this issue.

Presentation of the award will be made at a dinner meeting of the four Founder Societies and the Western Society of Engineers to be held in Chicago, Ill., February

Future AIEE Meetings

South West District Meeting
Houston, Texas, April 17–19, 1939

North Eastern District Meeting
Springfield, Mass., May 3–5, 1939

Summer and Pacific Coast Convention (combined)
San Francisco, Calif., June 26–30, 1939

Great Lakes District Meeting
Minneapolis, Minn., September 27–29, 1939

Middle Eastern District Meeting
Scranton, Pa., October 11–13, 1939

20, 1939. The award, consisting of an inscribed bronze plaque mounted upon a marble base, is given annually, when deserving candidates are found, by the award commission as "an honor conferred upon a brother engineer by his fellow engineers on account of accomplishment which pre-eminently promote the happiness, comfort, and well being of humanity." The commission is composed of 18 members, representing the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, AIEE, and Western Society of Engineers.

The award was founded in 1916 as the outgrowth of an endowment and suggestion by John Watson Alvord of Chicago that there should be some means of recognizing outstanding engineers who render pre-eminent service in promoting of public welfare. The idea was proposed originally to the Western Society of Engineers, which invited participation of the other societies.

Recognized as one of the highest honors that can be conferred upon an American engineer, the first award was made in 1919. Doctor Mead is the eighth member of the AIEE to receive this honor.

Subway Builder Dies. Robert Ridgway, consulting engineer, died at Fort Wayne, Ind., on December 19, 1938. Born in Brooklyn, N. Y., in 1862, Mr. Ridgway was engaged first in work on the location and construction of the aqueduct, dams, and reservoirs of the Croton system supplying New York City with water. From 1900 to 1905 he was engaged in the construction of New York subways, then returned to water supply as division engineer on construction of the Catskill system until 1912, when he again took up subway work. In 1921 he was appointed chief engineer of the Transit Commission, and when the Board of Transportation was established in 1924 to build the Independent Subway System, he was made chief engineer. In 1932 he was appointed consulting engineer, and retired the following year. Mr. Ridgway served frequently on studies of the Chicago subway problem, Boulder Canyon project, San Francisco bridge, New York vehicle tunnels, and on numerous other consulting boards. He was president of the American Society of Civil Engineers in 1925 and was elected to honorary membership in 1934.

South West District to Meet in Houston

A three-day meeting of the AIEE South West District will be held in Houston, Texas, April 17–19, 1939. Arrangements are being made for an interesting program of technical sessions, entertainment, and trips to places of interest in the vicinity.

Tentative arrangements for technical papers indicate that the subjects of general circuit theory, communication, power generation, pipe-line corrosion, rural-line performance, and supervisory control will be included in the program.

The personnel of the South West District meeting committee, which is making the arrangements for the meeting, is as follows: F. C. Bolton, *chairman;* L. T. Blaisdell, V. O. Clements, H. C. Dillingham, and Seth Evans. The chairman of the subcommittees are: N. F. Rode, meetings and papers; H. P. Haefer, entertainment; J. B. Arthur, attendance and publicity; L. Del Homme, transportation and inspections; H. F. Staacke, hotels and registration; and E. M. Wise, finance.

To Student Members Who Have Now Graduated:

The Institute membership welcomes you to the Associate grade and wishes you good luck and success in your chosen profession.

National Membership Committee

Columbia University Offers EE Scholarship

The governing bodies of Columbia University have placed at the disposal of the AIEE each year a scholarship in electrical engineering in the school of engineering of Columbia University for each class. The scholarship pays the annual tuition fees of $380. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the secretary of the University or to the national secretary of the Institute.

In a letter addressed to the national secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references, and photograph). A committee composed of W. I. Slichter, *chairman*, Francis Blossom, and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1938–39 will be June 1, 1939.

The course at the Columbia school of engineering is a graduate course which may be either elective leading to the degree of master of science or prescribed leading to the degree of electrical engineer. For the former, requirement for admission is the completion of a four-year course in electrical engineering as evidenced by a bachelor's degree from an approved institution. For the professional degree, the requirements are more specific as to course content and include a considerable proficiency in mathematics, physics, and chemistry, and some

San Francisco Bay Bridge a Convention Attraction

ELECTRIFICATION of the San Francisco-Oakland Bay Bridge railway, involving different voltages, offered many engineering problems in its design and construction. The project will be one of the high spots to be seen during the combined AIEE summer and Pacific Coast convention at San Francisco, Cal., June 26–30, 1939. As electrical engineers on the Pacific Coast are particularly concerned with the utilization and maintenance of electrical equipment, a well-rounded program of particular appeal to the engineer in industrial and commercial fields is under preparation.

knowledge of the humanities, as well as the usual undergraduate technical courses. The candidate is admitted on the basis of his previous collegiate record without undergoing special examinations. Other qualifications being equal, members of the Student Branches of the AIEE will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that Enrolled Students and others qualified will show a keen interest in this scholarship.

Winter Convention to Be Reported in March Issue

As this issue goes to press, the Institute's 1939 winter convention is under way at New York. Attendance at technical sessions and social events of this five-day meeting indicates that it continues the successful record of winter conventions. Registration for the first two days totaled 1,159 compared with 1,027 for the first two days of the 1938 convention, 827 for 1937, and 1,046 for 1936.

Presentation of the John Fritz and Edison Medals was made on the evening of January 25 to F. B. Jewett (A'03, F'12) and D. C. Jackson (A'87, F'12), respectively. An article by J. W. Barker (M'26, F'30) outlining the accomplishments of Doctor Jackson is published on pages 64–6 of this issue. A report of the convention and its special events is scheduled for inclusion in the March issue.

Future Meetings of Other Societies

American Chemical Society. Annual spring meeting, April 3–7, 1939, Baltimore, Md.

American Institute of Chemical Engineers. 31st semiannual meeting, May 15–17, 1939, Akron, Ohio.

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 13–16, New York, N. Y.
Open-hearth conference, April 26–28, Cleveland, Ohio.

American Physical Society. 226th meeting, February 23–25, 1939, New York, N. Y.
227th meeting, April 27–29, 1939, Washington, D. C.

American Society for Testing Materials. Committee week and regional meeting, March 6–10, 1939, Columbus, Ohio.

American Society of Civil Engineers. Spring meeting, April 10–22, 1939, Chattanooga, Tenn.

American Society of Mechanical Engineers. Spring meeting, February 23–25, 1939, New Orleans, La.

Machine and Tool Progress Exhibition, March 14–18, 1939, Detroit, Mich.

American Society of Refrigerating Engineers. Spring meeting, May 21–22, 1939, Hershey, Pa.

Association of Iron and Steel Engineers. Annual spring conference, March 27–28, 1939, Birmingham, Ala.

Canadian Institute of Mining and Metallurgy. Annual meeting, March 13–15, 1939, Hotel Frontenac, Quebec, Can.

René Thury Dead. The inventor of an early system of high-voltage d-c power transmission, Doctor René Thury, died recently in Switzerland at the age of 78. A native of Geneva, he was one of the pioneers in the design of electrical machinery and in railway electrification. In 1889 he devised a system for d-c transmission using several generators connected in series at the transmitting end to supply a number of motors, also connected in series, in one or more substations at the receiving end of the line. The current transmitted was kept constant by inserting or short-circuiting one or more machines, so as to alter the voltage. He also developed a sensitive voltage regulator for use with the system. Doctor Thury was elected an honorary member of the Institution of Electrical Engineers in 1934.

Current Items From American Engineering Council

National Patent Inquiry

A factual inquiry into the American patent system has been undertaken by American Engineering Council at the invitation of the National Industrial Conference Board. The inquiry is to be conducted by a separate special staff employed under direction of the patent committee of AEC, and financed from funds provided by the NICB outside the present income of AEC. Announcement of the plan was made by the conference board in the following statement:

A comprehensive investigation of the whole patent problem has just been started by the National Industrial Conference Board, independent fact-finding organization of management and labor. Technical phases of the investigation will be supervised by the committee on patents of the American Engineering Council, while the economic aspects will be analyzed by the conference board's economists under supervision of Doctor Robert F. Martin, director of the economic research division of the board. Much work on the patent situation has already been done by the AEC committee under the chairmanship of R. S. McBride, consulting chemical engineer. The other members of the committee are James H. Critchett, general manager, Union Carbide and Carbon Research Laboratories, Inc.; William M. Grosvenor, consulting chemist and factory engineer; Frank B. Jewett, president, Bell Telephone Laboratories, Inc.; Warner Seely, secretary, Warner and Swasey Company; and Kenneth H. Condit, executive assistant to the president, National Industrial Conference Board. Close cooperation with other organizations concerned with this problem is assured through representation on their patent committees by members of the board's staff.

Every phase of the patent problem will be studied by the experts of the conference board and engineering council. Five main headings are included in the outline of the inquiry. Under the general topic "Invention," there will be a study of the origins of inventions and a review of independent and organized invention. Such matters as costs, types of invention, work on inventions, use of patents, and foreign experience will also be covered.

Perhaps the most important subject of the five concerns the social and economic effects of invention. Under this heading the effects on consumers, labor, capital, and management will be studied in detail.

A third heading covers an examination of the patent system itself and the functioning of the Patent Office. Consequences of the patent system as shown by stimulation of invention and discovery are covered in another section. The final heading includes a critical review of the functioning of the patent system, and of current criticisms and proposed reform.

This co-operative undertaking makes possible the fulfillment of recommendations made for such a fact-finding study earlier presented by the patents committee of AEC to the annual assembly in 1937 and 1938, and approved by that body. The patents committee at a recent meeting approved of a detail plan of procedure and one division of the work has already been started. It is hoped that the complete undertaking will be finished within 12 months and that factual sections of the inquiry can be released before that time.

Nineteenth Annual Meeting Held in Washington, D. C.

Representatives of the member engineering organizations of American Engineering Council met in Washington, D. C., January 13–15, 1939, for the nineteenth annual assembly of AEC. The program included meetings of Council's principal committees, election of officers, and the annual "All Engineers' Dinner," at which Doctor Vannevar Bush (A'15, F'24) president of the Carnegie Institution of Washington, was guest speaker. The ninth annual conference of engineering societies' secretaries, devoted to discussion of the responsibilities of the organization secretary, was held concurrently.

Report of Executive Secretary

In his annual report to the assembly, Executive Secretary F. M. Feiker (M'34) summarized the work of AEC committees and staff. His report was divided according to the five objectives of Council's plans for the year, namely: public affairs function, public discussion function, engineers' embassy function, publicity function, and fact-finding function. Many of the activities have been reported from month in ELECTRICAL ENGINEERING.

Present officers whose terms expired were re-elected at the annual business session. AIEE representatives present were: C. O. Bickelhaupt (M'22, F'28), W. H. Harrison (A'20, F'31), C. R. Jones (A'16, M'30), John C. Parker (A'04, F'12, president), and National Secretary H. H. Henline (A'19, M'20). AEC officers for 1939, in addition to Mr. Feiker, are: *President*—William McClellan (A'04, F'12); *Vice-Presidents*—Mr. Bickelhaupt, R. E. Flandens, J. S. Dodds, and A. J. Hammond; *Treasurer*—L. J. Fletcher.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and the other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

The Paradox of Social Progress

To the Editor:

Planned education as a means for keeping a proper balance between unrestricted technological progress and social progress is fundamental. It is so fundamental that the uninitiated might take for granted that today it was a part of an established program for national development. The fact remains, however, that "planned education" as it exists today is an unco-ordinated activity carried on by many groups for various purposes and is extremely lacking in effectiveness from a national point of view. Education is not alone in this respect. In many other fields that bear directly on the welfare and happiness of our people we find the same ineffectiveness. The reason, I believe, lies in the nature of our government. In our democracy, the individual—the village—the city—the state—and the federal government still jealously maintain their own concepts of sovereign rights. The small school district in many states can still control the extent and quality of its children's education. Furthermore, it will resent any efforts of higher authority to establish standards and controls.

Planned education must be a comprehensive program—national in scope and inclusive of all education from the kindergarten through the university. The majority of discussions on education appearing in the engineering journals deal only with the changes that can be made in college courses to effect a broader and more socialized education. It is true that many beneficial changes can be made in the college curricula, but the needs for a planned education call for more than this minor adjustment. The deficiencies in our over-all educational program that can be mitigated by curricula changes in the higher institutions of learning should receive immediate attention. Such changes, however, should be considered only as an expediency.

The over-all planning of education is, to my mind, the only reasonable approach. As I see it, the task is tremendous. It would require the co-ordinated activity of all the major educational groups in the nation; it would require extensive research to test theory; and, above all, it would require the unstinting devotion of time and energy of men and women whose vision extends beyond the horizon of personal glory. The difficulties of such a program are many. The co-ordination of the entire activity and the establishment of a common goal would be problems enough to try the courage of the strongest souls. Beyond this, however, lie even greater difficulties in the inertia of the masses that reacts so slowly to educational changes, and in the desire of unqualified politicians to become partners of such a program in other than legislative capacities.

What the program for a planned education should be, I can only suggest. Perhaps I should not dare even to make a suggestion in this field, for as an engineer my background in educational matters has been gained only through my exposure to a standard American education, through a very limited participation in school administrative activities, and through general reading. Nevertheless, I will tread where angels might not dare.

The fundamentals that I believe should be included in a program for planned education are expressed in the following generalities:

Through the medium of a national board delegated to formulate standards and policies for all educational institutions and to direct and co-ordinate research, the following changes in the educational field should be made:

1. All teachers should be required to have, as a minimum education, a four-year college course that would thoroughly prepare them for the specialized fields they wish to enter.

2. The kindergarten should be made a part of our compulsory education, with an entrance age of four years. Teaching at this age should be based on a play educational program of such nature that when a child reached the age of six years he would be able to read, would have a knowledge of simple arithmetic, and would be able to adapt himself to group activity.

3. The elementary-school curriculum should then be adjusted so that the first year or year and a half of our present high-school subjects are covered in the first eight grades. This readjustment should be carried through the high schools, so that the university could gain the equivalent of two additional years for the many essential courses that now are omitted or only partially covered.

4. In the engineering schools the teaching of manual arts should be eliminated, or at least the time devoted to them should be materially reduced.

Very truly yours,
C. M. GROSS (A'27)

(Supervising Planning Engineer, Commonwealth Edison Company, Chicago, Ill.)

To the Editor:

Trusting that I may add to the fire kindled by Doctor George E. Hale in 1908, to which so much fuel has been added by Doctor Doherty's article, I submit the following discussion.

Doctor Doherty's concern about the chaotic state of today's world affairs is fully in accord with that of all who take time to think about what we are doing and where we are going.

Doherty sees only one way out—education. In that we agree, for certainly we can solve our problems if we but will to do so and study ways and means for accomplishing what we will.

When we acknowledge education as the way, we automatically close the doors to all thoughts of instantaneous utopias via the "Aladdin lamp route"—for education is ever a slow and sometimes a painful process involving great labor and sacrifice.

Scientists and engineers in their conquest against the physical burdens of man have achieved astounding success through the diligent application of brains, labor, and sacrifice.

This success, however, was not attained in the twinkling of an eye, but was accomplished inch by inch of a slow but constant shifting of the loads from the shoulders of men and the muscles of beasts to wood and water, then to coal and iron, and now to alloys and electricity.

Now we are learning that the world cannot be saved by science alone but must find a way to have all men learn the proper use of our mechanical gadgets as applied to the salvation rather than the destruction of civilization.

The engineering-education group is indeed fortunate when a man like Doctor Doherty, who after he has attained great success in the building of machines and factories and after becoming a powerful influence in industry, leaves industry and joins the educational group. In making this transfer he brings to our program of education a great knowledge of what colleges have taught and can tell us what has been useful and what has been ineffective in making college graduates efficient in the communities in which they live.

Out of this experience, he proposes a plan of education for engineers comprising for all a four-year program, one-fourth the time of which shall be devoted to a study of the humanities. For certain select men who show proficiency in the sciences and mathematics, he recommends graduate and research work carried on in conjunction with faculty members and with as close a relationship as possible to undergraduate students in order that the latter may profit by this contact.

This suggested program is indeed to me doubly interesting, because it is identically the program proposed just 30 years ago by the late Doctor George E. Hale, who, in contrast to the experience of Doctor Doherty, was an astronomer and idealist of great renown without any experience in the so-called industrial or practical affairs of the world.

Doctor Hale put his ideas about technical education into operation by becoming a member of the board of trustees of California Institute of Technology, formerly Throop Polytechnic Institute, and prescribing for it exactly the program now proposed by Doctor Doherty as one which should be carried on by a number of educational institutions, because as he says "effective public understanding cannot be realized by a mere handful of educated men; large numbers of them are necessary."

The success of California Institute of Technology in conducting for 30 years a program of technical education comprising four-year undergraduate courses with a large cultural subject content, all closely related to each other and to graduate

courses, abundant in research, carried on by graduate students and faculty members is a monument to this program of education. This program, also wholly free from unfortunate departmentalism, has paved the way for the wider adoption of such programs as advocated by Doctor Doherty. Indeed, this is the method of scientific approach—first a single trial by a small group, followed by a more general adoption.

I would like to supplement Doctor Doherty's plan for the new engineering curricula by calling attention to the fact that I think his criticism of certain humanity courses which have been given in engineering curricula and found wanting, have been deficient more because of failure to place in charge of those courses teachers selected with the same care as has been exercised in the selection of teachers for the technical subjects. Furthermore the names of the courses and the particular content thereof are secondary in value—the value thereof being determined almost entirely by the personality, ideals, and character of the teacher. All specifications for all teachers in engineering colleges should include a demand for ideals of spiritual and moral integrity so strong as to make every faculty member an example and teacher of those characteristics as well as a teacher of the subject matter inherent in his courses. Surely men from Mars or any other planet outside this earth must be amazed by the dumb actions of a people who with more than enough for everyone are unable to distribute and use intelligently the bounties that nature and industry have provided. I trust that every engineer will read Doctor Doherty's paper and rally to his support by becoming acquainted with the details of what is the trouble with world affairs and showing those not technically trained that sacrifice of personal gain is the only key that will open the way out.

Sincerely yours,

R. W. SORENSEN (A'07, F'19)

(Professor of Electrical Engineering, California Institute of Technology, Pasadena)

To the Editor:

The address by Doctor Doherty on "The Paradox of Social Progress" published in the November 1938 issue of ELECTRICAL ENGINEERING, pages 444–8, is most interesting.

Doctor Doherty calls for research by social scientists and speaks of the specific studies that have been made on labor relationships, racial relations, social security, etc. To my mind the most important research that has to be made today is on the co-ordination between science and religion. It seems to me that science is not fulfilling its responsibilities if it does not use as its basis the concept that men are creatures made up of certain spiritual as well as physical characteristics; the higher the type of the individual, the greater being that proportion of his personality that might be called his higher or spiritual self. The physical nature of man has not changed to any great extent since the beginning of recorded history, but there has been much improvement in his spiritual self, especially since the civilizations of Asia Minor and Greece.

Certainly all scientists know that feelings such as those of kindness, altruism, and patriotism, are distinct from the physical feelings of pain or hunger, or the lusts of primitive men. Also that as the control of the mind and the will over the physical instincts and emotions becomes greater, mankind becomes more cultured, civilized, and socially conscious.

As an illustration of how well-known publicists have this same thing in mind, I take the liberty of quoting from a recent article by Walter Lippman. He says:

> There has been no difference of opinion among the great teachers of the western world that there is in human nature a disposition to evil, that government is not government which cannot restrain it, and that religion is satanic that does not seek incessantly to overcome it. Long ago Plato fixed the image of man's moral problem as that of a charioteer who drives a pair of winged horses: "one of them is noble and of noble breed, the other is ignoble and of ignoble breed." And living as he did in an age of disaster and disorder, Plato added that "the driving of them of necessity gives a great deal of trouble to the charioteer.
>
> He perhaps had seen what we have seen, the use of civil authority to arouse the disposition to kill, to maim, to plunder, rather than to subdue and control these lusts. For he too lived in an age of revolution, and this is the very essence of revolution. For whatever the outward and temporary appearances of order and even of splendor, the certain sign that a people is in the grip of revolution is that government and what passes for the official religion surrender to, cultivate, and then use for their own purposes the slumbering barbarian in man's nature.

Of course, it is evident that Doctor Doherty is not at all unaware of this and there must be complete agreement to his suggestion of a planned education to properly cultivate "social understanding and human appreciation," but scientists should insist upon the great importance of this education, even to the extent of holding that without it, scientific training is of no permanent value. "Social understanding and human appreciation" should be spoken of as religious qualities, to which mankind must be passionately devoted.

Only when such devotion becomes general can mankind be definitely on its way to rise consciously above its primitive instincts and lusts.

It would seem that since our forefathers definitely separated the church from the state, certainly a decision from which no one can differ, it is difficult to have the training of our youth in these spiritual things in the hands of the state. Supposedly it is in the hands of our religious organizations. Unfortunately, however, most religious teaching is based on mysticism and on supposed revelations from on high. The teachings of science, especially since the universal acceptance of the theory of evolution and the survival of the fittest, have led to the breakdown of the religious faith of the average man, perhaps in many cases subconsciously. Consequently, what scientists should try to do, it seems to me, is to teach that "social understanding and human appreciation" is the only true scientific basis for a modern religion, in a world dominated by a continuously increasing scientific understanding of the laws, both physical and spiritual, which govern our actions.

Scientists seem to be afraid to interfere with what are supposed to be the prerogatives of religious leaders, but science is inevitably wedded to morals and religion. It would appear that by frankly stating and passionately believing that "social understanding and human appreciation" must be the basis of life, and the basis of our religion, we will be in a better position to solve the problems of our highly complicated modern life—"to achieve intelligent control of the forces that shape social progress."

Yours truly,

GUSTAVO LOBO (A'01, F'12)

(President, Kelvin Engineering Company, Inc., New York, N. Y.)

Personal Items

D. W. Mead (A'11, F'13) has been elected to receive the Washington Award for 1939. Details of the award are given elsewhere in the news section of this issue. Doctor Mead was born at Fulton, N. Y., March 6, 1862, and received the degree of bachelor of civil engineering from Cornell University in 1884. During the period 1885–87 he was city engineer of Rockford, Ill., and engineer for the Rockford Water Power Company. He was occupied as a contractor from 1887 until he established a consulting engineering practice at Chicago, Ill., in 1900. In 1904 the University of Wisconsin appointed him professor of hydraulic and sanitary engineering. He continued in his private practice at Madison, however, and was a member of the engineering board sent to China in 1914 by the American Red Cross and the Chinese Republic to study the problem of flood control on the Huai River. He was consulting engineer for the Miami Conservancy District (Ohio) during the planning and construction of the flood protection works in 1915, a member of the committee that investigated the 1927 Mississippi floods for the National Chamber of Commerce, and a member of the Colorado River Board appointed under joint resolution of Congress to pass upon the plans for the Boulder Canyon project. He is now chairman of the board that represents the federal government in

D. W. MEAD

L. W. W. MORROW

F. R. INNES

D. G. EVANS

the Chicago Sanitary District's present construction work. The University of Wisconsin conferred upon him the honorary degree of doctor of laws at the time of his retirement in 1931. He is a member of the firm of Mead and Seastone, with offices at Madison, and the New York firm of Mead and Scheidenhelm. Doctor Mead is the author of several books on hydraulics. In 1936 he was elected president of the American Society of Civil Engineers, of which he is an honorary member, and was awarded the society's Norman Medal. He is also a member of the American Institute of Consulting Engineers, The American Society of Mechanical Engineers, American Water Works Association, Western Society of Engineers, Tau Beta Pi, Sigma Xi, and many other organizations.

L. W. W. Morrow (A'13, F'25) has just been made western editorial director of McGraw-Hill publications with offices in Chicago, Ill. He will have general direction of editorial activities in the Middle West for the several McGraw-Hill papers. As an educator Mr. Morrow served Cornell, Yale, and Oklahoma universities in their engineering departments. In the publishing field he has contributed to the technical press over a long period of years and from 1922 to 1936 was connected with the editorial staff of *Electrical World*. Mr. Morrow was also frequently engaged as an engineering consultant on various projects and in November 1936, resigned as editor of *Electrical World* to become general manager of the fiber glass division of the Corning Glass Works, Corning, N. Y. He is a past chairman of the New York section of the AIEE (1927–28), a past director (1933–37), and has served the Institute on many committees during a period of nearly 20 years. At present he is a member of the technical program committee, the committee on planning and co-ordination, the membership committee, the Thomas Alva Edison foundation, and the engineers' council for professional development. He is chairman of both the Edison medal committee and the committee on constitution and by-laws.

F. R. Innes (A'25, M'26) has been made chief managing editor of *Electrical World* with headquarters at New York, N. Y. Mr. Innes was born at Port Huron, Mich., October 11, 1889, and started work with the Port Huron Light and Power Company. From 1913 to 1923 Mr. Innes was with the Detroit Edison Company, serving in various capacities from meter inspector to assistant distribution engineer. In 1920 he was assistant editor of the employee's magazine of that company. In 1923 he went to Longview, Wash., to be in charge of design, purchase of material, and installation of mill and yard lighting for Sessions Engineering Company. The next year he was transferred to Portland, Ore., by that company. During this period Mr. Innes began contributing articles to technical publications, and in 1925 he came to New York as assistant editor of *Electrical World*. Since 1927 he has been western editor of that publication, with headquarters in Chicago. He was chairman of the Chicago Section of AIEE in 1931–32. During the World War Mr. Innes served with the medical corps and later with the engineers corps of the United States Army. He has been granted patents in connection with meter and switchboard work.

D. G. Evans (A'20) recently became vice-president of the Wisconsin Gas and Electric Company, Kenosha. A biographical sketch announcing his appointment appeared in the January 1939 issue, page 53.

J. A. Tyvand (M'37) has been made chief engineer with supervision of all activities of the engineering department of the Wisconsin Gas and Electric Company at Racine, Wis. A native (1900) of North Dakota, Mr. Tyvand served with the United States Marine Corps during the World War. Following his graduation from the University of Minnesota in 1924, he went with the Milwaukee Electric Railway and Light Company as a junior engineer, but in 1929 left that company, where he was then starting engineer, to become system engineer for the Wisconsin Gas and Electric Company. In December 1936, he became electrical engineer for the Iowa Farm Bureau Federation at Des Moines, but returned to the Wisconsin Gas and Electric Company the following year as electrical engineer.

E. W. Seeger (A'16, F '36) has been made chief engineer of Cutler-Hammer, Inc., Milwaukee, Wis. Since his graduation from Ohio State University in 1913, Mr. Seeger has been with Cutler-Hammer serving in different capacities in shop and engineering departments. From 1928 until his recent promotion he was assistant chief engineer. Mr. Seeger has been granted many patents on electric-motor-control inventions. He has written many articles for publication in technical magazines and also a textbook on electromagnets. He was chairman of the Milwaukee Section of AIEE in 1929 and is a member of the codes and standards committee of the National Electrical Manufacturers' Association.

A. S. Moody (A'09) has been appointed commercial vice-president of the General Electric Company. Mr. Moody, a graduate of the University of California in 1906 with the degree of bachelor of science in electrical engineering, went with General Electric in 1907. He spent two years in the San Francisco, Calif., and Seattle, Wash., offices and then went to Portland, Ore., in 1910 as manager of the supply department of that office. For one year he was vice-president of the Pacific States Electric Company but returned to the General Electric Company in 1917 as assistant manager of the Portland office. In 1923 he was made manager of the Los Angeles office and in 1924 manager of the Northwestern territory with headquarters at Portland.

G. R. Shuck (A'19, M'20) has been made professor of electrical engineering at the University of Washington, Seattle. Professor Shuck was graduated from the University of Minnesota in 1906, spent a year as construction foreman with the Missouri River Power Company at Helena, Mont., and then a year in the research department of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. From 1909 to 1914 he was in the service department of the Westinghouse company at Seattle. He designed and supervised construction work with the Olympic Power Company of Port Angeles, Wash., for a year and then went to Kitchikan, Alaska, as superintendent of The Citizens' Light,

J. A. TYVAND

E. W. SEEGER

A. S. MOODY

Power and Water Company. For one year he was in charge of the electrical shops of the Polytechnic School in San Francisco and conducted classes in alternating currents for the University of California. He came to the University of Washington in 1918 as an instructor of electrical engineering and until recently had been an associate professor in his department.

C. L. Proctor (A'08) has been elected a director of Cities Service Power and Light Company. He now is vice-president and general manager of the Toledo Edison Company, Toledo, Ohio. A native of Virginia, he was graduated from Virginia Polytechnic Institute in 1902 and was awarded the degree of master of engineering there in 1903. From 1903 to 1908 Mr. Proctor was with the General Electric Company, Schenectady, N. Y.; from 1908 to 1915, general superintendent and purchasing agent for the Athens Railway and Electric Company, Athens, Ga.; and from 1916 to 1918 with the Empire District Electric Company, Joplin, Mo. From 1918 to 1919 he was vice-president and general manager of the Danbury and Bethel Gas and Electric Light Company, Danbury, Conn., but he returned in 1919 to become general manager of the Empire District Electric Company. In 1925 he left his position of vice-president and general manager of that company to accept a similar one with Toledo Edison.

H. R. Searing (A'20, F'30) has been appointed engineer of operation with the Consolidated Edison Company of New York, Inc., New York, N. Y. He had been serving as assistant engineer of that division, which is responsible for production, for system operation of generating plants and stations, and for all distribution operation, including apparatus, services, meters, and consumers' emergency services. Mr. Searing received his degree in electrical engineering from Cooper Union in 1916. Except for about three years, during which period he served as lieutenant and radio engineer with the United States Army, he had been with United Light and Power Company from 1913 until it became a part of the Consolidated Edison Company. Mr. Searing is credited with improvements to network devices and was closely associated with the development of the a-c network. He has served on several Institute committees.

J. J. Adams (A'36) is now working for the Zenith Radio Corporation, Chicago, Ill. Mr. Adams was graduated from the University of Colorado in 1934 and was granted his master of science degree in electrical engineering there in 1935. He formerly was engineer with the Philco Radio and Television Company at Philadelphia, Pa.

G. L. Knight (A'11, F'17) has been made engineer of construction and shops by the Consolidated Edison Company of New York, Inc., New York, N. Y., of which division he had been assistant engineer. Mr. Knight was graduated from the school of electrical engineering at Drexel Institute in 1900. Prior to his affiliation with the Brooklyn Edison Company in 1905, Mr. Knight did electrical work with the Philadelphia Electric Company, the United States Navy Yard, the Walker Electric Company, and the New York Edison Company. Mr. Knight is now vice-president of the Brooklyn Edison Company in addition to his position with the Consolidated Edison Company. Mr. Knight was vice-president of the AIEE (1926–28) and has served on many committees. He is currently serving on the AIEE Edison Medal committee.

L. B. Bonnett (A'18, M'25) has been appointed engineer of design and planning of the Consolidated Edison Company of New York, Inc., New York, N. Y., of which division he was made assistant engineer in 1938. Mr. Bonnett was graduated from Syracuse University in 1910 and was with the General Electric Company of Schenectady, N. Y., from 1910 to 1919. From 1919 to 1923 he was sales engineer with the General Electric Company, New York, N. Y., and then went with Brooklyn Edison Company. For the first three years he was inside plant engineer but became purchasing agent in 1926, which position he held until 1938.

H. L. Garver (A'25) has been made agricultural engineer with the Bureau of Agricultural Engineering, United States Department of Agriculture, Washington, D. C. Mr. Garver had been connected with the State College of Washington, Pullman, as rural electrification investigator for the past 13 years and is continuing this work with the Department of Agriculture. Following his graduation in electrical engineering from the State College of Washington in 1922 and prior to his return as rural electrification investigator, Mr. Garver was employed by the General Electric Company at Schenectady, N. Y. He is author and co-author of many bulletins and reports issued by the State College of Washington and of articles on agricultural engineering. He has been active in pest control and soil heating work with the American Society of Agricultural Engineers.

C. M. Hathaway (A'29) has established offices as a consulting engineer in Denver, Colo. A native of Paxton, Ill., Mr. Hathaway was graduated from the University of Colorado in 1927, was granted his master of science degree in 1928, and continued there as an instructor of electrical engineering for one year. Since 1929 he had been engineer with the General Electric Company at Schenectady, N. Y.

M. M. Rockwell (A'28, M'35) has been made electrical engineer in the production engineering department of the Lockheed Aircraft Corporation, Burbank, Calif. Mrs. Rockwell was graduated from the Massachusetts Institute of Technology in 1925 and received her degree in electrical engineering from Stanford University in 1926. From 1926 to 1928 she was employed in the testing department of the Southern California Edison Company and from 1928 to 1931 was technical assistant to the operating engineer. In 1931 Mrs. Rockwell was made assistant engineer of the Metropolitan Water District of Southern California. Since 1936 she has been a consulting engineer with offices in Los Angeles, Calif.

P. B. Harwood (M'36) has been made assistant chief engineer of Cutler-Hammer, Inc., Milwaukee, Wis. He has been employed by that company since his graduation from Carnegie Institute of Technology in 1917. Before the recent change Mr. Harwood was successively supervisor of the steel mill control division and then general engineering supervisor. Fom 1934 to 1936 he was assigned to the development of propulsion control for submarines. He holds many patents on controllers and is the author of "Control of Electric Motors," published in 1936. Mr. Harwood is a member of the Association of Iron and Steel Engineers and of the United States Naval Institute.

H. E. Dexter (A'14, M'17) general commercial manager of the Central Hudson Gas and Electric Corporation, Poughkeepsie, N. Y., and chairman of the sales committee of the Edison Electric Institute, has been made a member of the executive committee of the National Adequate Wiring Bureau.

H. E. Thompson (A'26, M'30) has been transferred to the engineering headquarters of the Anaconda Wire and Cable Company at Hastings-on-Hudson, N. Y., from its Pawtucket, R. I., plant where he had been electrical engineer in charge of rubber development and research. Before becoming associated with Anaconda, Mr. Thompson was with the Brooklyn Edison Company.

J. T. Bartek (A'24, M'30) Seattle, Wash., has been made associate electrical engineer at the United States Navy Yard, Puget Sound, Bremerton, Wash. Mr. Bartek was with the Marconi Radio Corporation from 1915 to 1916; instructor in radio with the United States Army at Fort Winfield Scott, Calif., in 1917 and 1918; and draftsman on electrical design on various Stone and Webster engineering projects on the West Coast since 1919.

L. H. Erickson (A'35) has been made junior engineer with the United States Bureau of Reclamation, Denver, Colo. Mr. Erickson formerly was a draftsman for the State Highway Department of Colorado.

R. K. Hellman (A'37) has received second prize for his paper "An Audio Frequency Spectrometer," entered in a contest conducted by the Scientific Apparatus Makers of America. He is employed by Transatlantic Research and Information Service, Inc., New York, N. Y.

F. A. Muschenheim (A'98, M'01) has been elected a director of the Broadway Association, New York, N. Y. Mr. Muschenheim, a graduate of Stevens Institute, has been president of the Hotel Astor Corporation, New York, for nearly two decades.

W. S. Sharp (A'38) is now assistant engineer for the Jackson-Bayley Electric Company, Canton, Ohio. A graduate of the University of Kentucky in 1937, he formerly had been assistant research engineer with the Pulp Products Company of Massillon, Ohio.

G. J. Gross (A'30) has received a fifth prize for a paper entered in a contest conducted by the Scientific Apparatus Makers of America. He is assistant transmission engineer with the Pennsylvania Water and Power Company, Baltimore, Md.

J. B. Troja (A'32) is now in charge of sales of all General Electric Company's products in Lima, Peru, S. A. Mr. Troja was graduated from the University of Washington in 1930 and in that year entered the General Electric Company at Schenectady, N. Y. Lately he had been sales engineer in the International General Electric Company.

E. F. Pearson (M'20, F'37) has been appointed assistant to the president of the Northwestern Electric Company, Portland, Ore. He recently was appointed assistant to the president of Pacific Power and Light Company, an affiliated company, as announced in the June 1938 issue of ELECTRICAL ENGINEERING.

N. H. Callard (A'16) has joined the staff of the vice-president and general sales manager of Westinghouse Electric and Manufacturing Company at Pittsburgh, Pa. Mr. Callard entered the employ of Westinghouse in 1912 and was, prior to his transfer to the East, central station manager of the San Francisco, Calif., office.

Ray Kernahan (A'36) has been made associate engineer of substation design at the Bonneville Project, Portland, Ore. Mr. Kernahan received the bachelor of science degree in electrical engineering from the State College of Washington in 1925 and had been electrical designer in the lighting department of the City of Seattle.

R. A. Beekman (A'13, M'27) has been appointed AIEE representative on the American Standards Association Sectional Committee on Electrical Installations on Shipboard—*C66*. Mr. Beekman is an engineer in the federal and marine department of the General Electric Company at Schenectady, N. Y.

F. A. Brown (A'32) has been made secretary-treasurer of Brown Brothers Lumber Company, Helena, Mont. A graduate of Montana State College in 1930, Mr. Brown was formerly assistant to the director of the north central division, Agricultural Adjustment Administration, United States Department of Commerce, Washington, D. C.

C. V. Armstrong (A'36) has become research assistant for the Iowa Engineering Experimental Station, Iowa State College, Ames. Mr. Armstrong was graduated from that university in 1935 and prior to his appointment was office engineer on condensers and centrifugal pumps for the Ingersoll-Rand Company, Chicago, Ill.

A. G. Dembrowski (A'38) has been made test engineer for the Hamilton Standard Propeller Company of East Hartford, Conn. Mr. Dembrowski received the degree of bachelor of science in engineering physics in 1937 and that of bachelor of science in electrical engineering in 1938 from the University of Michigan.

Franklin Clark (A'34) is now assistant electrical engineer for the Duro-Test Corporation of North Bergen, N. J. Mr. Clark was formerly with the Westinghouse Lamp Company at Bloomfield, N. J.

R. F. Tinnerholm (A'30) has been made manager of the switchgear sales division of the General Electric Company at Philadelphia, Pa. Prior to the recent change Mr. Tinnerholm had been section head of the switchgear department and has served the company in various capacities since 1907. He was in the air service of the United States Army during the World War.

H. W. Samson (A'24, M'30) has been appointed AIEE representative on the American Standards Association Sectional Committee on Drawing and Drafting Room Practice—*Z14*. Mr. Samson is engineer in charge of the data division of the General Electric Company, Schenectady, N. Y.

W. N. Zippler (A'20, M'38) has been appointed AIEE alternate representative on the American Standards Association Sectional Committee on Electrical Installations on Shipboard—*C66*. Mr. Zippler is an electrical engineer with Gibbs and Cox, Inc., New York, N. Y.

F. B. Hunt (A'37) has been made an electrical engineer in the distribution department of the Green Mountain Power Corporation at Burlington, Vt. Since his graduation from the University of Vermont in 1936, Mr. Hunt had been meterman with that company.

A. O. Lott (A'33) is now junior engineer with Porcelain Products, Inc., Parkersburg, W. Va. Mr. Lott was graduated from Georgia Institute of Technology in 1929.

Charles Wasserman (A'37) has received a fifth prize for a paper entered in a contest conducted by the Scientific Apparatus Makers of America. He is technical assistant with the Consolidated Gas, Electric Light and Power Company of Baltimore, Md.

S. G. Hibben (A'34) director of applied lighting of the lamp division of the Westinghouse Electric and Manufacturing Company (formerly Westinghouse Lamp Company), Bloomfield, N. J., has been appointed to the plan committee of the National Adequate Wiring Bureau.

R. G. Clay (A'38), a member of the 1938 class of the University of Illinois, is now draftsman for the Illinois Iowa Power Company, Champaign, Ill.

Obituary

André Eugène Blondel (A'05, HM'12) died November 15, 1938. Born at Chaumont, France, on August 28, 1863, he entered the École Polytechnique (class of 1883) after having been admitted to the École Normale Supérieure during the same year. Graduating from the École Nationale des Ponts et Chaussées in 1888, and given degrees in mathematics and physics in 1885 and 1889, he became an engineer in the Central Lighthouse Service, taking part in improvements made in the lighting service and planning the lenses and electrical machinery of many important lighthouses. In 1893 Professor Blondel was selected as the first occupant of the chair of applied electricity at École Nationale des Ponts et Chaussées, Paris; he continued his engagement with the lighthouse service until 1927, when he was inspector-general, and only recently retired to consulting work. He contributed many papers on electrical and optical subjects, and is credited with invention of the magnetic oscillograph, which he used in his study of alternating currents. In 1893 he explained mathematically the effect of inertia in the hunting of alternators; he also proposed the "two-reaction" theory of machines. A rational system of photometrical units proposed by him was adopted by the International Congress of Electricians at Geneva in 1896; other studies were carried on in arcs and wireless telegraphy. Professor Blondel was founder and president of the editorial staff of the publication *Revue générale de l'Électricité*. He was awarded prizes by the French Academy of Sciences in 1897 and 1898, and was a chevalier of the Legion of Honor, of which he was named commander in 1927. An honorary member of The Institution of Electrical Engineers, he was awarded that society's Faraday Medal in 1937. He was a past president of the Société française des Electriciens, and a member of numerous technical societies. Other honors he received included the Mascart Medal, the Gold Medal of the Franklin Institute, the Montefiore prize, and, in 1929, the triennial Lord Kelvin Medal.

Haywood Lewis Alderman (A'27, M'31) died on January 11, 1939, at Brooklyn, N. Y. He was born at Greensboro, N. C., August 14, 1883, and received his degree in electrical engineering from the North Carolina State College of Engineering in 1904. He spent six months in the test department of the Philadelphia Electric Company and two years in the test department of the General Electric Company, Schenectady, N. Y., before becoming operating engineer in 1906 with the Panama-American Corporation in Panama City. Following his return from Panama in 1909, Mr. Alderman spent ten years with Southern Power Company (now Duke Power Company), four years as a sales engineer, and three years with the Carolina Power and Light Company before going with Electric Bond and Share Company. Mr. Alderman had held various posts with that company, the last few years having been that of assistant engineer with Phoenix Engineering Corporation, New York, N. Y.

Llewellyn Willis Collings, Jr. (A'37) died at Detroit, Mich., on December 27, 1938. He was born at Riverton, N. J., on September 25, 1914, and received his degree in electrical engineering from Cornell University in 1936. He was a student engineer in the test department of the General Electric Company at Schenectady, N. Y., from the time of his graduation until he went with the Holley Carburetor Company in Detroit as engineer only a few months before his death. He was a member of Tau Beta Pi and Eta Kappa Nu.

Evan Parry (A'95), a partner in the firm of Preece, Cardew and Rider, London, England, died on December 17, 1938. Mr. Parry was born November 30, 1865, in North Wales. He received his degree of bachelor of engineering at Glasgow University in 1889. From that year until 1893 he was laboratory assistant to Lord Kelvin and then was appointed technical officer

and engineering assistant with the City of London Electric Lighting Company. In 1895 he became assistant to H. F. Parshall, then consulting engineer in England to the General Electric Company. Other electrical engineering posts held by Mr. Parry before he became associated with the consulting engineering firm of Preece, Cardew and Rider were with the government at Wellington, New Zealand, and with the English Electric Company, Ltd., London.

Walter G. Whitmore (A'90), East Orange, N. J., died on November 30, 1938. He was born at Plymouth, Mass., and was graduated from Massachusetts Institute of Technology in 1887. That year he worked with Leonard and Izard and the next year with the Chicago Edison Company. In June 1889, he went with the Edison General Electric Company in New York, N. Y., as an engineer. He was made head of the engineering department for the New York district of the General Electric Company in 1893, manager of the order department in 1911, and commercial engineer in 1924, which position he held until his retirement in 1931.

Fritz Uhlenhaut, Jr. (A'89, M'94) for many years chief engineer for the Pittsburgh Railways Company and Duquesne Light Company of Pittsburgh, Pa., died on January 1, 1937, according to information but recently received. Mr. Uhlenhaut was about 80 years of age and during recent years had been living at Providence, R. I. He was a graduate of Stevens Institute of Technology, Hoboken, N. J., and, before going with the Pittsburgh Railways Company in the early part of the century, had held engineering positions with the Brooklyn Edison Company, the Field Engineering Company of New York, and the Philadelphia Traction Company.

George Henry Horne (A'10) electrical engineer at Glendale, Calif., died December 6, 1938. He was born May 13, 1885, at Nineveh, Pa., and was graduated from Western University of Pennsylvania (now Pittsburgh University) receiving the degree of electrical engineer in 1907. That year he went with Westinghouse Electric and Machine Company and the next year with the Pittsburgh Transformer Company. In 1911 he was electrical engineer with Mordenskjold and Fisher at Nampa, Idaho. The next year he went with the United States Reclamation Service, Los Angeles, Calif., where he remained for about five years. From 1920 through 1933 he was with the Western Precipitation Company, Los Angeles, and has been located at Glendale since that time.

Membership

Recommended for Transfer

The board of examiners, at its meeting on January 19, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Hull, Blake D., chief engineer, Southwestern Bell Telephone Company, St. Louis, Mo.

1 to Grade of Fellow

To Grade of Member

Blenden, W. L., engineer, Southwestern Bell Telephone Company, St. Louis, Mo.

Bryant, E. P., chief operator, Boulder Power Plant, Boulder City, Nev.

Gillon, V. C., assistant to chief engineer, Oklahoma Gas and Electric Company, Oklahoma City, Okla.

Gilman, W. M., engineer, Jackson and Moreland, Boston, Mass.

Jones, R. A., engineer, General Electric Company, Buffalo, N. Y.

Kidder, A. H., assistant engineer of system planning, Philadelphia Electric Company, Philadelphia, Pa.

Nager, E. F., president, Nager Electric Co., Inc., Brooklyn, N. Y.

Tinling, H. B., engineer, Tinling and Powell, Inc., Spokane, Wash.

Wallis, John, system planning engineer, Oklahoma Gas and Electric Company, Oklahoma City.

9 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before February 28, 1939, or April 30, 1939, if the applicant resides outside of the United States or Canada:

United States and Canada

Adams, A. R., Des Moines Electric Company, Des Moines, Iowa.

Adams, C., Jr., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Allen, J. H., 2973 London Road, Oakland, Calif.

Allen, L. T., Allen Electric Company, Tulsa, Okla.

Allured, R. B., Cass City, Mich.

Arnold, W. O., Cooper Union, New York, N. Y.

Asbury, C. E., Illinois-Iowa Power Company, Bloomington, Ill.

Austin, H. G., Jr., 206 Sixth Avenue, Belton, Texas.

Bain, G. F., Copperweld Steel Company, New York, N. Y.

Baldwin, L. E. (Member), Memphis Light and Water Division, Memphis, Tenn.

Baugh, C., Stoll Oil Refining Company, Louisville, Ky.

Bejarano, J. R., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Birge, R. D., Jr., Louis Allis Company, Milwaukee, Wis.

Blodgett, P. C., Toltz, King, Day & Langford Electric Company, Houghton, Mich.

Bohrer, L. E., The Texas Pipe Line Company, Houston.

Bower, K. O., Commonwealth Edison Company, Chicago, Ill.

Boyd, W. E., Air Corps, United States Army, Randolph Field, Texas.

Brain, J. W., Black and Veatch, Consulting Engineers, Kansas City, Mo.

Brennecke, C. G., University of Toledo, Toledo, Ohio.

Bronski, C. R. (Member), Commonwealth Edison Company, Chicago, Ill.

Bunin, J., Department of Public Works of New York City, N. Y.

Burton, G. D., Idaho Power Company, Pocatello.

Buttler, G. H., Jr., Johnson and Johnson, New Brunswick, N. J.

Cannon, A. H., 703 Madison Street, Athens, Ala.

Carmichael, H. A., 50 Trowbridge Street, Cambridge, Mass.

Chu, L. J., 290 Massachusetts Avenue, Cambridge, Mass.

Clendineng, R. B., 14 Belvidere Street, Springfied, Mass.

Constantine, J. M., Constantine's Engineering Service, Newburgh, N. Y.

Cook, K. C., Bureau of Power and Light, Los Angeles, Calif.

Curtis, T. B., Tennessee Electric Power Company, Chattanooga.

Dash, C. C. (Member), Hertner Electric Company, Cleveland, Ohio.

Davenport, J. A. (Member), Corps of Engineers, United States Army, Cincinnati, Ohio.

DeCroce, G., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

Dejadon, H. H., Daniel Woodhead Company, New York, N. Y.

DeLaucie, H. S., Maydwell and Hartsell, Inc., San Francisco, Calif.

DeWitt, D., Columbia University, New York, N. Y.

DuFresne, A. F., General Petroleum Corporation, Los Angeles, Calif.

Eckles, W. W. (Member), Gulf States Utilities Company, Beaumont, Texas.

Edwards, F. E., Jr., Firestone Tire and Rubber Company, Akron, Ohio.

English, L. L., Commonwealth Edison Company, Chicago, Ill.

Erichson, W. B., Jr., 7129 Mt. Vernon Street, Pittsburgh, Pa.

Erickson, D. H., Ellerbe and Company, St. Paul, Minn.

Erickson, W. H., Duquesne Light Company, McKeesport, Pa.

Ferber, A. L., General Motors Corporation, Grand Rapids, Mich.

Flowers, H. L., Proctor and Schwartz, Inc., Philadelphia, Pa.

Fowler, E. D., Northwestern Bell Telephone Company, Des Moines, Iowa.

Freed, J. H., Olson Construction Company, Lincoln, Nebr.

Gallup, B. E., RR 2, Wolcottville, Ind.

Ganther, C. E., Cleveland Electric Illuminating Company, Cleveland, Ohio.

Garrett, E. S., Philadelphia Electric Company, Philadelphia, Pa.

Gates, S. H., Southern Bell Telephone and Telegraph Company, Louisville, Ky.

Gedge, G. F., 2042 Bronx Street, New York, N. Y.

Gentry, R. D., Kansas Gas and Electric Company, Wichita.

Gentzel, P. M. (Member), Ohio Public Service Company, Elyria.

Gilbert, P. G., Westinghouse Electric and Manufacturing Company, Philadelphia, Pa.

Glenn, A. B., Automatic Winding Company, Harrison, N. J.

Glueckstein, H., Globe Union Manufacturing Company, Milwaukee, Wis.

Goetz, L. P., Nephi Fielding and Company, Shelley, Idaho.

Goodheart, C. F., Texas Agricultural and Mechanical College, College Station.

Goudy, P. R., Bailey Meter Company, Cleveland, Ohio.

Gowdey, M. V., United States Navy Department, Bremerton, Wash.

Graham, O. (Member), Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Graugnard, J. B. C., Caire & Graugnard, Columbia Sugar Factory, Edgard, La.

Hadley, C. F., Magnolia Petroleum Company, Dallas, Texas.

Hall, J. I., Trumbull Electric Manufacturing Company, Plainville, Conn.

Hallaman, J. C., Texas Electric Service Company, Fort Worth.

Hanson, F. E. (Member), Western Electric Company, Kearny, N. J.

Hanville, S. R., Jr., Ashland Laboratory and Supply Company, Ashland, Ohio.

Hauss, F. E., Hauss and Company, Norwood, Ohio.

Hauss, W., 114 E. 32nd Street, New York, N. Y.

Hawley, K. F., Pennsylvania Water and Power Company, Baltimore, Md.

Hellmann, K., Empire Electric Company, Brooklyn, N. Y.

Herdman, T. T., 408 South Goodwin, Urbana, Ill.

Herman, G. L., Bradford Armature Works, East St. Louis, Ill.

Hess, E. F., Brooklyn Edison Company, Inc., Brooklyn, N. Y.

Hess, W. T. (Member), Louisiana Power and Light Company, New Orleans.

Hill, H. H., Halliburton Oil Well Cementing Company, Hebbronville, Texas.

Hodgson, G. T., University of Toronto, Toronto, Ont., Canada.

Hok, C. G. M., 500 Riverside Drive, New York, N. Y.

Hotchkiss, T. M. (Member), Southern California Edison Company, Ltd., Los Angeles, Calif.

Hoyt, T. C., Consolidated Edison Company of New York, Inc., New York, N. Y.

Huff, J. F., Southwestern Bell Telephone Company, Wichita, Kans.

Jacobson, C. R., Memphis Light and Water Division, Memphis, Tenn.

Jarchow, T. L., Northern States Power Company, Minneapolis, Minn.

Jewell, J. H. (Member), American Steel and Wire Company, Worcester, Mass.

Johnson, L. W., Harlowton, Mont.

Johnson, V. O., University of Missouri, Columbia.

Johnson, W. A., Central Illinois Light Company, Peoria.

Jones, I. (Member), Rural Electrification Project, Oklahoma City, Okla.

Kellogg, D. S., W. L. Maxson Corporation, New York, N. Y.
Keskinen, A. R., Erie Resistor Corporation, Erie, Pa.
Kimball, B. C., E. B. Badger and Sons, Boston, Mass.
Kingsley, W. H., Ideal Electric and Manufacturing Company, New York, N. Y.
Kirkman, O. C., Jr., Chattanooga Electric Power Board, Chattanooga, Tenn.
Kleemola, W. K., Vulcan Electric Company, Lynn, Mass.
Kolstad, C. K., International Business Machines Corporation, Brooklyn, N. Y.
Kramer, W. B., Duquesne Light Company, West Bridgewater, Pa.
Kreger, C. H. (Member), Public Service Company of Northern Illinois, Chicago.
Krook, P., 4039 11th N. E., Seattle, Wash.
Krug, J. A. (Member), Tennessee Valley Authority, Knoxville.
Kuppinger, H. R., R. F. D. No. 4, Auburn, N. Y.
Kuretich, F. J., Colorado Fuel and Iron Corporation, Crested Butte, Colo.
Kurz, C. Jr., United States Government Printing Office, Washington, D. C.
Lacy, W. R., Board of Transportation, City of New York, New York, N. Y.
Lamphere, R., Westinghouse Electric and Manufacturing Company, Wilkinsburg, Pa.
Lang, W. Y., Bell Telephone Laboratories, Inc., New York, N. Y.
LaRoche, A. R., Electrical and Gas Association, New York, N. Y.
Leggio, J., Westinghouse X-Ray, Long Island City, N. Y.
Llewellyn, F. E., Gallatin E 12, Soldiers Field, Boston, Mass.
Loeffler, H. F., Wisconsin Telephone Company, Milwaukee.
Logerwell, F. L., Henningson Engineering Company, Inc., Omaha, Nebr.
Lusis, F. A., Boston Edison Company, Allston, Mass.
Malcolm, J. A., Jr., Jericho, Long Island, N. Y.
Masters, H. W., J. H. Rotz Engineering Company, Indianapolis, Ind.
Matthews, N. W., Rural Electrification Administration, Washington, D. C.
Matthews, R. W., W. N. Matthews Corporation, St. Louis, Mo.
Matthias, L. H., Allen Bradley Company, Milwaukee, Wis.
Mayhard, C. A., Indiana Steel Products Company, Valparaiso, Ind.
McCart, S. O., General Electric Company, Cleveland, Ohio.
McIntosh, C., Jr., Buffalo Niagara Electric Corporation, Niagara Falls, N. Y.
McLellan, J. A., Consolidated Edison Company of New York, Inc., New York, N. Y.
Milewski, C. A., Hart Manufacturing Company, Hartford, Conn.
Miller, C. E., Los Angeles Bureau of Power and Light, Boulder City, Nev.
Miller, N. C., Northern States Power Company, Minneapolis, Minn.
Miller, R. F., B. F. Goodrich Company, Akron, Ohio.
Mitchell, F. DuV., Shallcross Manufacturing Company, Collingdale, Pa.
Monson, C. F. Jr., Yakima Valley Junior College, Yakima, Wash.
Morgan, J. S., Allis-Chalmers Manufacturing Company, Knoxville, Tenn.
Morton, J. R., Memphis Light and Water Division, Memphis, Tenn.
Moser, R. C., Cincinnati Gas and Electric Company, Cincinnati, Ohio.
Murray, D. (Member), Chase Brass and Copper Company, Waterbury, Conn.
Nagel, F. D., General Electric Company, San Francisco, Calif.
Nagel, T. J., Columbia University, New York, N. Y.
Nelson, A. L., Indianapolis Broadcasting Incorporated, Indianapolis, Ind.
Nesbitt, A. D., New York Central Railroad, Cleveland, Ohio.
New, W. R., Tennessee Valley Authority, Norris, Tenn.
Nolph, C. A., Union Pacific Coal Company, Rock Springs, Wyo.
Norvak, S., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Oberdorf, R. C., Edison Light and Power Company, York, Pa.
Olsen, B. Jr., General Electric Company, Schenectady, N. Y.
Palmer, T. B., General Electric Company, Pittsfield, Mass.
Pann, S. G., Department of Water and Power, Los Angeles, Calif.
Parsons, J. E., Chesapeake and Potomac Telephone Company, Washington, D. C.
Pierce, J. R., Texas Electric Service Company, Fort Worth.
Pollock, R. C., Carolina Power and Light Company, Lumberton, N. C.
Pugh, P. S., American Gas and Electric Service Corporation, South Bend, Ind.
Reinhard, C. K., New York Telephone Company, New York, N. Y.
Richardson, H. C., Duquesne Light Company, Pittsburgh, Pa.
Rietow, L. A., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Riggs, L. S., Samson Tire and Rubber Company, Los Angeles, Calif.
Robuck, J. B., Texas Power and Light Company, McKinney.
Rogers, R. N., Cleveland Electric Illuminating Company, Cleveland, Ohio.
Rose, F. H., Pacific Gas and Electric Company, Chico, Calif.
Rossi, O. L., Trumbull Electric Manufacturing Company, Plainville, Conn.
Ryder, H. S., General Electric Company, Schenectady, N. Y.
Rystrom, R. H., University of California, Riverside.
Safford, M. G., 28 Blodgett St., Springfield, Mass.
Sawyer, E. C., Gulf States Utilities Company, Beaumont, Texas.
Schenck, H. H., Tennessee Electric Power Company, Chattanooga.
Schlick, A. M., General Delivery, San Francisco, Calif.
Schwarz, F., Philadelphia Storage Battery Company, Philadelphia, Pa.
Sedgwick, R. P., Los Angeles Bureau of Power and Light, Boulder City, Nev.
Seppala, H. T., Canadian General Electric Company, Toronto, Ont., Canada.
Shaner, M. S., Southwestern Bell Telephone Company, St. Louis, Mo.
Sherer, C. M., Pennsylvania Water and Power Company, Holtwood.
Shimuff, L. H., % Thomas H. Allen, Memphis, Tenn.
Shoemaker, D. K., Philadelphia Electric Company, Philadelphia, Pa.
Shook, W. K., Jr., Georgia School of Technology, Atlanta.
Short, H. D., Canada Wire and Cable Company, Leaside, Ont., Canada.
Siegfried, C. E., Bell Telephone Company of Pennsylvania, Pittsburgh.
Skog, J. H., 4305—15th Avenue N. E., Seattle, Wash.
Sloan, R. R., International Business Machines Corporation, Endicott, N. Y.
Small, R. M., Bowie Switch Company, San Francisco, Calif.
Stieber, T. R., Westinghouse Electric and Manufacturing Company, Philadelphia, Pa.
Strout, F. H., Northern Indiana Public Service Company, Hammond.
Strozier, C. C., Tennessee Eastern Electric Company, Johnson City.
Swenton, C. S., Consolidated Edison Company of New York, Inc., New York, N. Y.
Tanchel, M., Mandell Institute, New York, N. Y.
Taverner, R. B. (Member), Commonwealth Edison Company, Chicago, Ill.
Thiel, E. A., Swift and Company, Chicago, Ill.
Thiesfeld, H., Rural Electrification Administration, Washington, D. C.
Tomberg, S., Tomberg Electric Supply Company, Wilkes-Barre, Pa.
Treuhaft, M., % J. C. Batchelor, Consulting Engineer, New York, N. Y.
Trochu, L., Soil Conservation Service, Sheridan, Wyo.
Turner, R. B. (Member), Susquehanna Electric Company, Conowingo, Md.
Uptegraff, R. E., Jr., R. E. Uptegraff Manufacturing Company, Pittsburgh, Pa.
Vincens, E. (Member), Tennessee Valley Authority, Knoxville.
von Brecht, C. H., Southeast Missouri Telephone Company, St. Louis.
Vreeland, W. G. E., Consolidated Edison Company of New York, Inc., New York, N. Y.
Wagner, R., Jr., New York Telephone Company, Brooklyn, N. Y.
Wall, H. R., Tennessee Electric Power Company, Chattanooga.
Warman, W. C., Chesapeake and Potomac Telephone Company, Washington, D. C.
Warskow, M. A., W. K. Kellogg Company, Battle Creek, Mich.
Watson, J. P., Tennessee Valley Authority, Guntersville Dam, Ala.
Waugh, C. L., United States Department of Interior, Bonneville Project, Portland, Ore.
West, B. C., CCC Company 4607, Camp Dubois DG-98, Dubois, Idaho.
White, H. P., The Chesapeake and Potomac Telephone Company of Virginia, Richmond.
White, W. S., Bell Telephone Company of Pennsylvania, Philadelphia.
Widener, B. M., Virginia Polytechnic Institute, Blacksburg.
Williams, N. A., International Nickel Company, Ltd., Copper Cliff, Ont., Canada.
Willis, J. M., City of Florence, Florence, Ala.
Wright, R. L., Anaconda Wire and Cable Company, Pawtucket, R. I.
Young, C. L., West Texas Utilities Company, Abilene.

Total, United States and Canada—203

Elsewhere

Askew, W. B., Borough of Watford, Electricity Department, Watford, England.
Egan, D. G., % R. L. Suggs, Humble Oil and Refining Company, Netherlands Indies.
Jaggis, S. S., % Midland Bank Ltd., Stafford, England.
Jain, R. S. (Member), Benares Hindu University, Benares, India.
Krishnaswamy, S., Mysore Electrical Department, Bangalore, India.
Smith, M. S. S. (Member), Hawera Hospital Board, Hawera, New Zealand.

Total elsewhere—6

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, recently are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question

ELECTRICAL MACHINERY, a Practical Study Course on Installation, Operation and Maintenance. By F. A. Annett. Second edition. New York and London, McGraw-Hill Book Company, 1938. 429 pages, illustrated, 9 by 6 inches, cloth, $3.00. This book aims to provide a course of home study for electricians, power-plant men, and others who work with electrical machinery. Theory and practical applications are explained in clear, simple language, beginning with the fundamentals of electricity and continuing through the usual equipment. This new edition has been considerably enlarged and thoroughly modernized.

PRINCIPLES of ELECTRICITY and ELECTROMAGNETISM. By G. P. Harnwell. New York and London, McGraw-Hill Book Company, 1938. 619 pages, illustrated, 9 by 6 inches, cloth, $5.00. A textbook covering, in addition to the basic laws and general concepts, such subjects as dielectrics, thermionic vacuum tubes and their circuits, chemical, thermal and photoelectric effects, and radiation. The emphasis is on the experimental and scientific rather than on the mathematical or engineering aspects of the subject. Vector notation is used and a unification is achieved by the consistent use of absolute practical units and the electromagnetic approach to magnetism.

ELEKTROTECHNIK, Einführung in die Starkstromtechnik. Vol. 2. Die Gleichstromtechnik. (Sammlung Göschen 197). By I. Herrmann. Sixth edition. Berlin, Walter de Gruyter & Company, 1938. 144 pages, illustrated, 6 by 4 inches, cloth, 1.62 rm. An elementary text on d-c work, presenting the theory of d-c generators and motors, describing the construction and operation of d-c machines, and covering the general subject of transformers, rectifiers and lead, and alkali storage batteries.

GRUNDLAGEN der ATOMPHYSIK. By H. A. Bauer. Vienna, Julius Springer, 1938. 249 pages, illustrated, 8 by 5 inches, paper, 12.60 rm. A discussion of the development and present status of atomic physics, considered under the three main headings: Particle structure of matter; wave structure of matter; and the combination wave-corpuscular theory.

HISTORY of RADIO to 1926. By G. L. Archer. New York, American Historical Society, 1938. 421 pages, illustrated 10 by 6 inches, cloth, $4.00. A survey of the development of radio from the earliest attempts at communication of signals to the status of the industry in 1926. Concerned mainly with persons, events and organizations; nevertheless the fundamental discoveries and experiments leading up to the practical use of the art are treated.

MacRAE'S BLUE BOOK and Hendrick's Commercial Register. 46th Annual Edition, 1938-39. New York and Chicago, MacRae's Blue Book Company, 1938. 3,604 pages, illustrated, 11 by 8 inches, cloth, $15.00. Provides an index of manufacturers and wholesalers with their local distributors, with addresses; an indexed classified list of manufacturers; a directory of commercial bodies, banks, railroads and warehouses in towns of one thousand or more population; and a list of trade names.

RIGHT WAGES and ABUNDANCE. By A. G. McGregor. New York, E. P. Dutton and Company, 1938. 316 pages, 8 by 6 inches, cloth, $2.50. Discusses production and consumption capacities, wages and prices, with particular reference to their interrelation. The economic policies of Great Britain and the United States since the World War are examined, and the adjusting of bank credits, exchange policies, and trade factors for the establishment of international amity are considered.

METAL COLORING and FINISHING. (Authorized translation from the second revised edition.) By R. Krause. New York, Chemical Publishing Company, 1938. 222 pages, tables, 9 by 6 inches, cloth, $5.00. Metal coloring and finishing by chemical, mechanical and electrical processes are discussed from theoretical and practical points of view, with references to patents.

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☐ 37-866	Appleman	*The Cause and Elimination of Noise in Small Motors
☐ 38-53	Calvert	†Amplitudes of the MMF Harmonics for Fractional Slot Windings
☐ 38-54	Porter	*Positive-Grid Characteristics of Triodes
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* These papers have been published in the TRANSACTIONS section of ELECTRICAL ENGINEERING.
† These papers have been published in the 1938 AIEE Transactions volume.

Transactions

Papers and Discussions Comprising Pages 35–82 of the 1939 Volume

Co-ordination of Physics With Electrical Engineering

By J. M. BRYANT
MEMBER AIEE

THE early departments of electrical engineering in American universities were outgrowths of courses developed in physics. In most engineering colleges some member of the physics faculty offered application courses in physics for engineering students and after a few years these developed into a complete curriculum with a separate faculty for electrical engineering in parallel with the older civil and mechanical engineering curricula.

The early courses were mostly descriptive in nature with some emphasis on design of electrical machinery. The only text available was that of "Dynamo Electric Machinery," a two-volume text on d-c machinery by S. P. Thompson, an English author. The early American texts in a-c theory were inadequate, with very few proofs, and the minimum of mathematics. The early papers and texts of Doctor C. P. Steinmetz were the first to lay a proper foundation in mathematical development for advances in a-c theory. Practicing electrical engineers were not properly prepared in either physics or mathematics to understand these texts and Doctor Steinmetz adopted calculus methods for the solution of differential equations and series methods for solution of long transmission lines, so that his texts might be of real use to these engineers. To the early text on "Alternating Current Phenomena" he added others, including his well-known text on "Transient Electric Phenomena" and then one on "Electrical Engineering," a book adopted as an elementary text for students in some engineering colleges. In each of these texts, the solution of circuits by the use of the complex number was introduced and the machines were reduced to circuits for their solution. This was a revolution in method, since most previous authors had developed a new theory for each machine and the machine and the circuit did not fit together.

Many colleges were slow to adopt these newer mathematical methods of analysis partly from the inertia and poor preparation of the faculty and partly from the lack of proper emphasis along these lines in the fundamental fields of physics and mathematics. When students, trained in these new methods of analysis, were absorbed by the industry, and more emphasis was placed on fundamentals of analysis rather than on descriptive methods, a distinct gain was possible in the development of better designs for electrical devices and machines and the extension of the field was much accelerated. The rapid advance of electrical engineering in the past 25 years is due in a large measure to the ability of engineers to analyze the problems mathematically and to measure the quantities involved with exactness.

At the present time adequate texts are available in a-c theory for both undergraduate and graduate instruction of electrical-engineering students and as reference texts for practicing engineers. In these texts the authors have adopted mathematical proofs with application to modern machinery and transmission circuits. Much praise is due to the willingness of publishers to encourage better texts in this field when profit has not been their only motive.

In the field of communication the early texts were mostly descriptive of the equipment and circuits with little emphasis on calculation or of background physical principles. Development in research by physicists in the field of electrical discharges in gases and the development of the theory of electron emission have made possible the development of vacuum tubes which have revolutionized the whole field of wire communication and have brought forth the newer field of radio communication. The vacuum tube and improvements in transmission circuits have changed the entire field of transmission of speech and music over wires by introducing repeaters at frequent intervals along the line which with better circuit equalization have made long-distance wire-communication clearer and of higher fidelity than local communication was a comparatively few years ago. With the advance of radio from that of telegraphy to that of telephony, it has been possible to link all phones in one international system. The early courses in vacuum tubes and radio were developed in some universities in the department of physics and in others in electrical engineering.

The vacuum and gas-filled tubes have invaded the power field of electrical engineering and these new applications are rapidly expanding into the fields of circuit control and d-c transmission of power. The early carbon-filament vacuum incandescent lamp was displaced by others using tungsten filaments, at first having a vacuum and later by those filled with inert gases. These advances were brought about by research in the fundamental physical phenomena. Other developments along parallel lines have produced the numerous electric lamps using electrical discharges in gases and vapors at low and medium pressures. Further research by physicists in gas laws and electric discharges have laid a background for the study of lightning, for the X-ray tube, and for various new subdivisions of the atom, giving rise to new products and new technique in both physics and engineering.

The two fields of physics and electrical engineering are again becoming more closely allied, so that courses may be developed by teachers in either department and taken by students in both departments. At the University of Minnesota, courses in acoustics, in electronics, vacuum tubes, and communication, both wire and radio, are taught in electrical engineering while those in the fundamental gas laws and nuclear physics are taught in physics. These courses are taken as majors by graduate students in either department.

In the field of mathematics a similar

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The Co-ordination of Mathematics and Physics With Electrical-Engineering Subjects

By WALTER A. CURRY
FELLOW AIEE

NO DEFENSIVE arguments are required to justify the need and desirability of co-ordination between mathematics, physics, and electrical-engineering subjects; such co-ordination must exist to some degree in every electrical-engineering curriculum and the essential objective of this symposium is to create a discussion of views and to reveal the instrumentalities whereby such co-ordination may be and is achieved.

Fundamentally, the initial objective of an engineering program of studies is to inculcate in the student an appreciation and grasp of that approach to the solution of problems which has been designated as the scientific method, represented by an ordered sequence consisting of observation, analysis, generalization, and application.

This method rests squarely upon the science of physics, which treats of matter and energy, and the science of mathematics, which sets up the philosophy and techniques whereby the quantitative relationships of physical laws and principles may be expressed, investigated, and evaluated. The student entering upon the course in physics, having previously prepared himself in mathematics, is therefore qualified to fuse the two fields in the combined relationship which is basic to the scientific method. Thus, in the Columbia program, the student has a year of mathematics before entering upon the course in general physics, and two years of mathematics and one year of physics before he reaches his first course in electrical engineering subjects.

Training the student, in his physics courses, to search for the fundamental principles upon which a statement of the problem may be formulated, to translate such statement into its mathematical equivalent, to solve this equivalent and to interpret the results so obtained, represents an invaluable educational process. Such training actually expresses co-ordination with subsequent engineering courses to the highest degree, since these courses will utilize the same principles in attacking problems presented by their subject matter.

Such co-ordination does not imply that there shall be no overlapping of subject matter; a student in the electrical-engineering subjects may be effectively "tuned" to new material if the instructor gives a brief résumé of the underlying physical laws, in spite of the fact that these are known to have been discussed in previous courses. This not only refreshes the student's memory, but reemphasizes the alliance between the new applications and the earlier subject matter, problems in both of which are amenable to the same scientific method for their attack and solution.

To keep such résumé within reasonable limits, however, there must be effective co-ordination between the electrical-engineering subjects and physics. At Columbia, this is provided in part through informal and voluntary discussion between instructors in the two fields. It is accepted as part of their duty, that instructors in physics inform themselves specifically as to the knowledge of physics assumed in engineering courses by members of the engineering-school staff, and conversely, those giving instruction in the engineering school are charged with keeping definitely informed on the instruction in general physics. There are available in the electrical-engineering department detailed specifications of the subjects treated in general physics, which vitalized by interpretive discussion, provide those elements necessary to the efficient collaboration of the two fields.

Referring to the student in engineering, the objectives of these courses (in general physics), recently defined by a faculty committee, are as follows:

1. To give the student knowledge of the phenomena of matter and energy, and training in how they can be quantitatively analyzed and classified by measurement and theory, so that he may make use of this knowledge and training as a common basis of introduction for further study in various courses in engineering.

2. To give the student a knowledge of the interrelationships of the different branches of physics, and an understanding of the development of the science of physics, its direction of progress, and the developments that have not as yet proceeded to the point of engineering application.

Thus, the desired co-ordination between the physics courses and the engineering subjects which follow is recognized in the first objective, while the second is essential to the broad engineering program. It may be noted incidentally that only about 60 per cent of the groups which attend the general course in physics are headed for engineering; the course is taught as physics and is designed for all students who intend to

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co-operation has been experienced as with that of physics. In spite of the handicap of poorer preparation in mathematics of students entering our colleges, the mathematics departments of the universities have been able to prepare these students for their undergraduate work in calculus. By a co-ordination of this work with a greater application of mathematics in electrical-engineering courses during the junior and senior years, the student is now better prepared than formerly at the end of his senior year. The department of mathematics has also co-operated by offering courses in differential equations and advanced calculus, in operational analysis, vector analysis, functions of complex variables and matrices for graduate students in electrical engineering and physics to parallel new methods of analysis required by these students and by industry. Through the use of these fundamental methods electrical engineering has passed from an experimental to an exact science. The hope for future advances in the field of electrical engineering still lies in the application of mathematics and physics to the solution of new problems and the design of new equipment.

Discussion

For discussion see page 43.

major in science, including those who will specialize in physics and those who will enter engineering.

The electrical-engineering subjects rely on the preceding work in physics to establish clear concepts and understanding of the fundamental laws and relationships governing elementary magnetic phenomena, electrostatics, and the laws of current flow in simple d-c circuits. Dimensional relationships and systems of units are important adjuncts. The subject of light, as discussed in the physics course, is planned to establish a sound basis for the subject of illuminating engineering in the subsequent electrical-engineering program, and similarly treatment of sound and wave motion, atomic physics, and the conduction of electricity through gases, form foundation elements for the subjects of communication and electronics. Knowledge of the laws of motion for rotating bodies, treated in physics and mechanics, is manifestly essential to the proper understanding of generator and motor performance discussed in subsequent electrical-engineering courses.

The co-ordination between electrical-engineering subjects and mathematics follows along lines similar to those relating to the work in physics. The earlier mathematics subjects (analytic geometry and the calculus) coming throughout the first and second years, provide a basic training which is essential to all fields of engineering. These subjects are given in the college and are taken by mixed groups, of which possibly 60 per cent are planning to enter engineering. The major objective of this two-year sequence of formal mathematics is the development in the student of an appreciation and clear understanding of the science which is mathematics, coupled with the attainment of a measure of skill and confidence in the application of this science to the solution of problems, many of which have their framework in the fields of mechanics and physics.

This two-year sequence is followed in the third year by a one-semester course in engineering mathematics which discusses such items as:

Fourier series, line integrals, ordinary and partial differential equations, complex number operations, determinants, elliptic integrals, empirical equations, harmonic analysis, nomographs, probability, gamma and Bessel functions.

Naturally, with a content of this scope projected for a one-semester course, the student does not proceed to great depth in any one of the above items. The objective is rather to acquaint him with them, and to give him some indication of their application to practical problems, particularly in the field of electrical engineering. The subject of differential equations, however, touched upon in a preceding course in the calculus is, in this course, carried considerably further, about one-half of the time being devoted to this item.

This course was instituted at the request of the electrical-engineering department and its objective is "to equip the student with the mathematical mechanism commonly used in all branches of engineering, but pointed particularly toward electrical engineering." It represents a directed effort to advance the student from what may be termed the "minimum" type of educated man to the "superior" type, these types being defined as follows:

The "minimum" type knows the important physical concepts and is fairly well aware of their function in engineering problems, but he is not very strong in the mathematical management of these physical concepts. His strength is intuitional and experimental. He may be a valuable man.

The "superior" type has all that the minimum type has, but in addition he has learned with his concepts of physics, the mathematical formulation of them. This man has superior capacities for design and research.

The liaison between mathematics and the electrical-engineering subjects is provided by an "engineering-minded" member of the department of mathematics, Professor L. P. Siceloff, who conducts the course in engineering mathematics, and who is the author of the preceding definitions. This link is an effective one and through it there flows an easy interchange of suggestions and requirements which may arise from time to time.

The sequence in mathematics beginning with analytic geometry, continuing through calculus, and concluding with engineering mathematics, provides the necessary skill to enable the student to master the mathematical aspects of his subsequent work in electrical-engineering subjects.

Furthermore, these courses, jointly with those of physics, are directly utilized in the fourth year, by a two-semester course in electrical-engineering problems, the purpose of which is to give the student an indelible realization of the intimate relationship which exists between electrical engineering, mathematics, and physics.

The means chosen for accomplishing this objective is a series of very carefully constructed problems which are so designed that their solution demands clear analytical procedure, combined with a certain degree of resourcefulness and perspicacity, while at the same time the student is required to understand and explain fully the origin of the underlying fundamental ideas and their extension and application to the problem at hand.

In the lectures that accompany this course the student has pointed out to him the connection between the general fundamental idea and the engineering applications. The fundamental ideas are always expressed in their general mathematical form, often using mathematics not available to the student at the time the principle was originally introduced in physics. The student learns the application of mathematical processes to engineering problems and the significance of mathematical operations interpreted in terms of physical and engineering phenomena.

As has been indicated in the foregoing discussion of co-ordinating courses, an essential factor in such co-ordination resides in the establishment of close personal relationships between the instructors of the several departments concerned, enriched by a cordial spirit of co-operation and motivated by a high idealism in the objectives to be sought and attained. But co-ordination, once achieved, cannot be left to maintain itself. The inevitable and necessary revision which the subject matter of an engineering or science course undergoes as time brings new developments and viewpoints in those fields, demands that such co-ordination be re-examined at intervals to insure its continued existence. At Columbia, during the past several years, this has been accomplished through committees, with membership representative of the departments involved, including those of mathematics and physics. Such a committee is serving at the present time, and it is anticipated that similar committees will be appointed from time to time in the future.

In conclusion it may be said that there is an essential unity to all knowledge, and the student in electrical engineering will value and appreciate his early and later courses more highly if there is an efficient continuity throughout his schedule of studies. This will be accomplished if there exists a planned co-ordination of his three major fields, namely mathematics, physics, and electrical engineering.

Discussion

For discussion see page 43.

Mathematics and Physics in Engineering

By MICHEL G. MALTI
MEMBER AIEE

MANY definitions are given of an engineer. For the purpose of this discussion I would define an engineer as a scientist who uses physics and mathematics to promote the welfare of mankind. His use of physics and mathematics presupposes a thorough knowledge of them and demands that he be capable of:

(*a*) Reducing his engineering problems to fundamental physical facts.

(*b*) Expressing the physical facts in mathematical form.

(*c*) Deriving from the mathematical statement the desired mathematical result.

(*d*) Interpreting the mathematical result physically.

These points are so important that they justify further elucidation. Let us illustrate them through the familiar problem of determining the transient current in a series circuit, with resistance and inductance, which is suddenly subjected to a constant electromotive force:

(*a*) The physical facts here involved are that the applied electromotive force is consumed in drops through the resistance and inductance.

(*b*) The mathematical expression of the physical facts is:

$$E = ri + Ldi/dt$$

(*c*) The derivation of the mathematical result consists in solving this differential equation and obtaining

$$i = (E/R) + Ke^{-Rt/L}$$

(*d*) The interpretation of this result is that the current may be anything depending upon K. Hence we resort to the physics of the problem and assert that the current is zero at the instant $t = 0$ when the electromotive force is impressed. This gives $K = -E/R$ and hence the current for this particular initial condition is:

$$i = (E/R)(1 - \epsilon^{-Rt/L})$$

I have used this simple illustration to show the four processes involved in all engineering problems. The degree of ease or difficulty of one or the other of these processes varies with the nature of the problem. But each process exists in every engineering problem no matter how difficult or easy it may be.

Now it so happens that part *c* (the actual derivation of mathematical results) is something that an engineer need not master because he can always resort to the mathematician for the performance of this task. But every engineer should be a master of parts *a*, *b*, and *d* because neither the physicist nor the mathematician can be of assistance to him in this matter.

I doubt if there exists any disagreement among engineers about these statements. We also admit that the majority of engineers lack these essentials otherwise we would not be holding this symposium. We therefore conclude that something is wrong either in our teaching of physics and mathematics or in the proper co-ordination of these subjects with engineering courses or in both.

All these are facts which we agree upon. What we do disagree upon are the real causes of this condition and the remedies to be adopted. I do hope that when this symposium is ended we shall have attained a clearer insight into the real causes of the trouble and shall have adopted a course of action which constitutes a fundamental and effective remedy.

I shall now endeavor to give some of the causes and suggested remedies as I have collected them through talks with educators, students, and engineers and through personal observation and experience. This will then be succeeded by a critical analysis of them and a suggested solution of the problem.

(*a*) *Incompetence of Mathematics and Physics Teachers.* Some educators trace our woes to the teachers of mathematics and physics. They assert that these teachers do not understand the point of view of the engineer and are, therefore, unable to teach him these subjects. Both mathematicians and physicists are prone to emphasize facts which are essential to them but which are utterly useless in engineering applications. Furthermore physicists and mathematicians do not know engineering problems. Hence they are not capable of discerning what is and what is not essential to engineering. Obviously the remedy here consists in having mathematics and physics taught to engineers by engineers.

(*b*) *Lack of Co-operation.* Another group agrees that the viewpoint of the engineer should be stressed in both mathematics and physics courses but are less antagonistic to teachers of mathematics and physics. They are inclined to take a little of the blame upon themselves and ascribe the trouble to lack of proper co-operation between teachers of engineering on the one hand and teachers of mathematics and physics on the other. Some of the remedies here suggested include:

1. Frequent conferences between faculty members with a view of co-ordinating efforts.

2. Actually supplying the departments of mathematics and physics with typical engineering problems which these departments could use for illustrative purposes.

3. Telling the teachers of mathematics and physics what is and what is not essential in engineering and requesting that only essential facts be stressed in teaching physics and mathematics to engineers.

(*c*) *Lack of Time.* A third group blames neither the teachers of engineering nor the teachers of physics and mathematics. They assert that competence and co-operation exist to as high a degree as may be expected. Time or rather the lack of it is the cause of our trouble. Indeed the engineering curriculum is so crowded and the student is so rushed with his courses that there exists no time to stress the mathematical and physical aspects of engineering. To train an engineer to correlate physics, mathematics, and engineering is truly a time-consuming and a very exacting task. Moreover since time cannot be conserved through the elimination or revision of engineering courses there appears three possible remedies.

1. Extension of the engineering course to more than four years.

2. Offering graduate courses in colleges to men who expect to engage in strictly engineering work.

3. Delegating, to industry, the responsibility of training engineers through advanced courses.

(*d*) *Incompetence of Engineering Teachers.* A very small fourth group is willing to shoulder the whole blame and admit that, sometimes, the cause of the trouble can be traced to the very teachers of engineering themselves. This group argues that there is a golden opportunity for engineering teachers to correlate mathematics and physics in their own courses. Such teachers should stress the physical laws and mathematical relations which form the bases of engineering applications in order that the student may form a concrete picture of how physics and mathe-

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matics are used by the engineer. If the contention of this group is true, then the remedy obviously consists in having, on our engineering faculties, men who combine a good engineering training with a thorough and comprehensive knowledge of mathematics and physics. Such men should, moreover, possess the gift of conveying their thoughts in a logical, clear, and comprehensive manner to their students. The task of the engineering teachers thus becomes most exacting and their selection requires the most careful scrutiny of college presidents, deans, and department heads.

It would appear that elements of truth exist in the contentions of all four groups. Let us, however, examine them a little more critically.

(*a*) While it is desirable that physicists and mathematicians do appreciate the engineer's point of view, such appreciation is of precious little help to the freshman and sophomore student who has no inkling of what engineering is! To tell a freshman that the laws of gases are used in connection with engines, turbines, and air-conditioning machines might attract his interest. But it means little or nothing to him because he knows nothing about the design or operating characteristics of such machines. Nor would it profit the sophomore much when he is advised that Faraday's law of induction is the basis of the design and operation of all electric machines because he knows little if anything about electric machines. It still means less to an immature student to be told that a linear differential equation of the first order with constant coefficients represents a series circuit with R and L or with R and C because such a circuit is just as mysterious to him as the differential equation itself. Indeed, to an immature freshman and sophomore, engineering is more strange than the physics and mathematics he studies. It would appear, therefore, that the time to show the application of physics and mathematics to engineering problems is not during the freshman and sophomore years but during the junior and senior years when the student is actually engaged in studying engineering. It thus becomes incumbent on the *teachers of engineering* rather than those of physics and mathematics to demonstrate and elucidate the application of these basic sciences to engineering problems.

(*b*) There is much to be gained from conferences between teachers of engineering and of the basic sciences provided these conferences are well planned and well directed and provided that a sincere effort is exerted by all to see one another's point of view. Such conferences should have for their object:

1. The understanding, by mathematicians and physicists, of the processes involved in the solution of engineering problems as outlined earlier in this discussion.

2. The understanding by engineers of the processes of analysis which a mathematician utilizes in formulating and solving his problem and the physicist uses in making his discoveries of physical laws and in correlating physical phenomena.

To my mind it would be disastrous to dictate to a physicist or mathematician what he should or should not teach engineering students or how he should present the subject matter. To dictate the contents of a course would emphasize the utilitarian and exclude the interest aspect of education. To dictate methods of presentation would rob the student of the mental enrichment which comes out of studying several modes of attack and establish in his mind narrow tracks and processes of reasoning which might or might not prove helpful in attacking his future problems.

(*c*) The problem of lack of time is a serious one and I would welcome the extension of the engineering course to more than four years provided all educational institutions throughout the country agree to do so. But I insist that, even in four years, engineering colleges can do better by their students if they require less substitution in formulas, less graph plotting, less slide-rule work, and more brain work. In fact, even if the engineering course is extended to five or six years I would recommend that the present mode of running some courses, with the idea of consuming the student's time rather than exercising his brain, be abandoned, and the courses be so changed that time is spent in thinking rather than in slide-rule pushing and graph plotting.

(*d*) It is obvious that all these recommendations lead to one effective solution —the improvement of engineering faculties. The remedy lies in having engineering teachers who are not only well-trained engineers but who are also good mathematicians and physicists. The time is past when a knowledge of algebra and of Ohm's and Faraday's laws were all the tools that an electrical engineer needed. The time is gone when an engineer jokingly remarks that the place of an integral sign is on the violin. Such mathematics as functions of complex variables, functions of real variables, theory of sets, theory of groups, calculus of variation, ordinary and partial differential equations, advanced algebra (tensors, etc.), and vector analysis are commonly used in the solution of engineering problems. As to physics, the electron theory comprising conduction of electricity through gases, electron emission, photoelectricity, X-rays, etc., and such subjects as quantum mechanics, light, heat, and others are just as essential to the electrical engineer of today as Ohm's law and Faraday's law of electromagnetic induction were to the pioneer engineer. Engineering teachers should realize these facts and prepare themselves to meet present-day demands.

The following evolutionary process may be suggested to improve our present faculties in the larger universities:

(*a*) Have all graduate students in engineering who are working for a degree of doctor of philosophy take mathematics and physics as minors.

(*b*) Appoint assistants from among these graduate students and keep records of their scholarship and teaching ability, as well as their character and personality.

(*c*) Select from among the assistants those who show most promise and encourage them to specialize along various lines. These men, upon receiving their degree of doctor of philosophy should be appointed as instructors.

(*d*) Make research accomplishments and teaching ability necessary (although not sufficient) conditions for promotion.

(*e*) Have the faculty keep in touch with industry in order to follow the developments of the time.

If this policy is adopted by our leading educational institutions every first-class college would, within a brief period of perhaps ten years, have an excellent faculty and the problem we are discussing in this symposium would become of minor importance!

But I hear the voice of the personnel man reminding me that over 80 per cent of our graduates finally end in sales offices or in executive positions with very little possibility of their ever using physics, mathematics, or even engineering and that the remaining 20 per cent or perhaps even 10 per cent who actually do engineering work are trained in special industrial courses! So why all this fuss about knowledge of mathematics and physics and their correlation with engineering subjects? To the personnel man and his ilk I say:

The purpose of all education is mental training. College courses are but vehicles to attain this end. In these courses facts are learned and quickly forgotten. What the student retains are the mental processes which he unwittingly acquired while he pursued these courses. If one's mind is fertile and receptive and his tutors are alert, enthusiastic, and competent, then one's mentality should be so

Courses to Develop Facility in the Use of Mathematics and Physics in the Solution of Engineering Problems

By B. R. TEARE, JR.
MEMBER AIEE

IN RECENT years engineers and teachers have recognized[1,2] that many graduates lack facility in the use of mathematics and physics in the solution of engineering problems. Appearing to know the principles of science that underlie engineering, the young graduates frequently cannot apply them correctly in new situations. It is evident that the development of the requisite facility depends upon first, mastery of the basic sciences and second, adequate training in their application. Thus, there is need for two different kinds of co-ordination of mathematics and physics with electrical engineering: co-ordination of the departmental teaching activities for most effective instruction, and co-ordination of the subject matter in the student's mind for most effective use.

Co-ordination of the first kind may be achieved by close co-operation between the faculties of the departments concerned. Various ways of obtaining the co-operation are available.[3,4] To cite an example, there is a committee for this purpose at Yale University, composed of representatives from the mathematics, physics, mechanics, and various engineering departments. Committee meetings, held frequently, provide opportunities for the interchange of points of view and for suggesting, where desirable, a redistribution of the emphasis placed on particular topics in the various courses. Although the first type of co-ordination is recognized as essential, it does not remove the necessity for the other type.

The student has been well instructed in the basic sciences but too often has not received adequate training and practice in their co-ordinated use. Such training and practice can be given by means of a course organized for this purpose. For example, the advanced course in engineering of the General Electric Company,[2] working with a selected group of graduates in industry, has for one of its objectives the development of facility in the application of mathematics and physics to the solution of engineering problems, and is notably successful in attaining this end. It is the purpose in what follows to discuss a program to give such training to the student before he leaves college.

For the last six years the electrical engineering department at Yale has given junior and senior courses of three hours each comprising a unified two-year program of this type, and also a parallel one-year graduate course. The subject matter, and manner of conducting the courses are selected for the most effective co-ordination of the basic sciences with electrical engineering. The introduction of new topics is subsidiary to the development of a thorough understanding of the old.

Since the aim is to develop facility in the use of mathematics and physics in the solution of engineering problems, naturally the chief emphasis is on problem solving, both in class discussions and in assignments. As far as possible, problems are selected which present new situations, where the solutions are to be obtained not by substitution in handbook formulas but by the application of such fundamental principles as, for instance, Newton's laws of motion, or Fourier's law of heat conduction. Two examples, representative of the more difficult assignments, are given for illustration.

1. It is proposed to support a motor by means of an elastic mounting in order to reduce vibrations that are transmitted through the mounting to the supporting foundation. The vibrations originate in centrifugal forces due to mechanical unbalance, or in pulsating electromagnetic forces, and occur at definite frequencies. The effectiveness of the mounting is to be measured by a quantity called transmissibility, which for vibrations of a given frequency is the ratio of the steady-state amplitude of the force transmitted to the base through an elastic mounting to that transmitted through a rigid mounting.

For an elastic mounting, which has damping, and considering only vertical vibrations,

(*a*) Determine the transmissibility in terms of frequency and system constants.

(*b*) Illustrate the result by sketched curves of transmissibility as a function of vibration frequency for various values of damping.

(*c*) Discuss the value of an elastic mounting which has little damping, if the vibration frequency is about half the natural frequency of the vertical vibrations of the motor on its mounting.

2. In a proposed thermocouple ammeter, the current to be measured is passed through a thin straight metal strip supported between two massive terminal blocks. One junction of a thermocouple is placed at the midpoint of the metal strip, the other junction on one terminal block, but electrically insulated from it. The thermocouple is connected to a galvanometer.

(*a*) Express the temperature difference between junctions in terms of the voltage drop between terminal blocks, dimensions, and thermal constants.

(*b*) What length of heating element will give the largest temperature difference between junctions for a given power loss?

(*c*) What are the disadvantages of this type of meter?

That these problems are of practical engineering interest is shown by the fact that they were presented in technical papers appearing during the last five years.[5,6] The students were not given the

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1. For all numbered references, see list at end of paper.

developed, when he completes his college training, that he can:

(*a*) Study independently of teachers.
(*b*) Synthesize isolated facts.
(*c*) Generalize from fundamentals.
(*d*) View facts objectively.
(*e*) Visualize things.
(*f*) Do original work.

I know of no mental faculties that are more essential to an engineer than the above. This holds true whether he be a salesman, a designer, an executive, a teacher, or a gang boss. Moreover I know of no courses which develop these mental faculties more intensively and more sharply than mathematics, physics, and engineering.

Discussion

For discussion see page 43.

references until after they had obtained solutions.

In all the assignments, except the relatively few exercises employed for drill in new topics, the student is given an unfamiliar situation in which simplifying assumptions must usually be made in order to obtain a solution, and in which as far as possible he must select the variables with which to work. The required physical principles and mathematical techniques, however, will have been covered in class work and perhaps in other assignments.

Through the duration of the courses much emphasis is placed on the orderly arrangement of thought processes in the solution of problems. The arrangement which is applicable to problems of the deductive type, has been discussed elsewhere[1] and may be summarized in the following steps:

I. Stating the problem and specifying the desired result. The student is to use his own words and illustrate with sketches where possible.

II. Formulating a plan of solution, which includes

(*a*) Selecting a principle to be applied;

(*b*) Making whatever simplifying assumptions may be necessary;

(*c*) Planning the treatment as far as it may be foreseen.

III. Stating in precise English the implication of the chosen principle in the particular problem.

IV. Translating the statement of III into mathematical form which includes

(*a*) Specifying notation;

(*b*) Selecting co-ordinates;

(*c*) Writing III as an equation.

V. Solving IV*c*, which usually includes introducing additional relations, and perhaps also additional simplifying assumptions. Should a solution of IV*c* be impossible, a fresh start applying a new principle is to be made.

VI. Testing the solution

(*a*) For dimensional homogeneity;

(*b*) With extreme values assigned to variables;

(*c*) For reasonableness in the light of experience;

(*d*) For possible effect of the simplifying assumptions.

While this formulation may appear inflexible, it is so only as regards the inclusion of all the steps and in order. Many problems require the use of more than one principle; in other words the desired solution can be considered to result from the simultaneous application of a number of principles. However, this organization of thought processes implies that but one is to be chosen to start the solution, and there may be some latitude in the choice. Moreover, there may be another kind of selection to make since some physical laws are merely different expressions of the same fundamental truth. Any one of these may be used in a given case, although often a particular one leads to a more direct solution.

The principles which are discussed in the courses and used in the solution of problems comprise the general fundamental laws of mechanics, heat transmission, electrostatics, magnetostatics, and circuit theory, such as Newton's laws of motion, conservation of energy and of momentum, the principle of superposition, Fourier's law of heat conduction, Newton's law of cooling, Coulomb's and Gauss's laws for electric and magnetic fields, Ampere's and Kirchoff's laws, Faraday's electromotive-force law, and the constant-linkage theorem, to name but a few. The student has encountered most of these previously in mechanics and physics and indeed can usually state them with fair accuracy. He is expected, however, to develop such understanding of the laws, their range of application, and the physical quantities they relate, that he can select appropriate ones for the solution of a new problem.

Considerable time is devoted to the review and use of familiar mathematics and to the treatment of more advanced techniques, including the solution of second-order linear differential equations with constant coefficients, elementary vector analysis, Fourier series, symmetrical components, and dimensional analysis. These new topics are introduced in the solution of particular problems and later generalized.

The analogous behavior of electric circuits, mechanical systems, and heat conduction systems, expressed in exactly similar equations, provides a natural unification of portions of mathematics and physics with engineering, and is of great assistance in augmenting the student's understanding. Likewise the broad analogy among the space fields of electrostatics, magnetostatics, gravitation, thermal and electric conduction, and fluid flow described by similar vector equations and identical field maps, furnishes another natural means of integrating the subject matter. A consideration of the points of difference between analogous systems is as helpful in building up understanding as the mention of matters of similarity.

Classes are conducted as seminars, where each student contributes to the discussion, rather than by formal lectures. Supplementary laboratory exercises are given in the junior year, in which the student is required first to solve a given problem theoretically and then verify his result experimentally. In the senior year the work culminates in projects, individual development problems usually requiring work in the laboratory, and short enough so that two or three can be completed. Such projects, for example, may be the combined theoretical and experimental study of dynamic braking of d-c machines, or of the performance of thyratron inverters. About a quarter of the senior course is devoted to this kind of activity.

The relation of these two undergraduate courses to the program as a whole has been described elsewhere.[1] They are required of all the undergraduates in electrical engineering, and each course is allotted one-fifth of a year's time. They are co-ordinated with each other and with the other electrical engineering courses to unify the program as a whole. At the end of the senior year the student's grasp of the entire technical portion of his work in all four years is tested in a searching departmental, or comprehensive, examination.

In conclusion, the courses to develop facility in the use of mathematics and physics in engineering problems have these essential features:

(*a*) Training in an orderly thought process;

(*b*) Integration of the student's knowledge of the basic sciences;

(*c*) Extensive practice in the solution of actual engineering problems.

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Discussion

For discussion see page 43.

Co-ordination of Mathematics and Physics With Electrical-Engineering Subjects

By THEODORE H. MORGAN
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IN RECENT years all branches of engineering have experienced rapid growth and progress. Technological advancement has been accompanied by an increasing realization of the breadth and scope of the profession. College curricula have been altered and adjusted in attempts to meet changing conditions. We have been forced to realize that the solution of our educational problems is not to be found in an increased amount of work or in adding further courses to already overcrowded curricula, but rather in more complete co-ordination and unification within the programs themselves. Due to the manner in which the engineering curricula have been built up through the years, new subjects being added from time to time as was found necessary, we are in danger of thinking of a curriculum as being composed of separate blocks, i.e., so much mathematics, so much physics, chemistry, and so forth. Our problem is to break down the well-defined boundaries of these blocks so that they will be combined to form a unified and coherent whole. We might compare the curriculum to a painting for which the artist carefully chooses a number of colors which are not used separately in blocks, but are harmoniously blended and intermingled in a complete picture.

Let us look at mathematics and physics. When taught only as the science of order, giving quantitative and magnitudinal relations of pure numbers, mathematics loses much of its value to the engineer. The student should become familiar with this subject as providing an indispensable and powerful tool of the profession. In teaching mathematics, as the beauty and mystery of pure numbers is unfolded to his mind, the student should learn at the same time the practical value of the subject in dealing with physical relations. This can best be accomplished through a high degree of co-ordination between the courses in mathematics and those dealing with the physical sciences, of which the subject of physics is perhaps the best example. The co-ordination that I have in mind requires close relationship between departments. The instructor in mathematics must be thoroughly conversant with the course in physics, and vice versa, so that the work is carried forward simultaneously—the mathematician applying the laws of physics in his mathematical developments at the same time that the physicist is building in the student's mind an understanding of a fundamental law which is being given definite form and expression in mathematical symbols. The learning of general mathematical principles, manipulations, and technique, should go hand in hand with their use and application. The student would thus realize that in mathematics he has a powerful and precise instrument which can be used with perfect exactitude to solve physical problems. As this usefulness became increasingly evident both mathematics and physics would take on new interest and importance in his mind.

The subject of physics by its very nature covers a greater field than any other course in the curriculum. It is the foundation for all engineering courses, which are largely specialties in physics having important practical value. It thus becomes essential that the engineering student form proper habits of thought in such matters. His introduction to principles which are new to him should be accomplished in such a way as to appeal to his common sense and intuition. In contrast to the memorization of stated formulas the student should be required to perform for himself the much more important and difficult task of expressing physical laws and facts in mathematical terms. Once this is accomplished the mathematical developments and manipulations would follow simply and easily. The acquisition of fundamental knowledge would go hand in hand with the development of scientific analysis, requiring deep-seated understanding and proper habits of thinking and reasoning, and the student would recognize physics and mathematics as belonging to fundamental science, together forming the foundation of engineering.

Furthermore, the student who elects an engineering course has a natural interest in and zeal for his chosen field of work. The proposed plan would capitalize upon this enthusiasm by permitting the student to start his college course with work which he would recognize as possessing the essential properties of engineering, instead of feeling that he must wait for about two years before starting work of this character. Not only would his interest be greatly enhanced thereby but aptitudes would be discovered at an earlier date.

Under the present plan a student may come to graduation without full appreciation of the unity that exists throughout all of his work. Relationship between courses, while an interesting speculation, may never be fully understood. Individual courses are frequently viewed as something which must be passed and thus "gotten out of the way" before more advanced work can be undertaken.

The question might be raised as to whether certain important educational losses would not be sustained through the introduction of such a plan. There is no doubt that the study of mathematics and physics as pure science can have great value to the engineering student. The very nature of these subjects gives the student a broad philosophy and viewpoint with respect to science which it is difficult to develop in engineering courses because of their limitations. These values need not be lost but might even be increased by proper teaching of the co-ordinated work. To accomplish this, great care should be taken to insure that the student is made to fully appreciate the *complete unity* and the *simple beauty* that exists in natural law. Co-ordination of science subjects would give a better opportunity to develop a more complete understanding of the underlying correlations between the various elements of science. Respect and esteem for the unity, beauty, and truth in natural law would be enhanced by a fuller and deeper appreciation of the interrelationships and parallelisms which constantly present themselves.

Considering the co-ordination of mathematics and physics as the first step, the second step in our proposed program would be to unify and co-ordinate all electrical-engineering courses themselves. These subjects can all be brought together into one closely woven whole and developed as one broad course from the initial elementary work to the time of graduation. Laboratory and classroom courses should not exist separately, but each division of the work should receive

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investigation in the laboratory at the same time it is being discussed in the classroom. Thus theory and practical understanding would be developed together in a logical manner. Comprehensive knowledge and understanding would thus be obtained as a result of thorough investigation from different points of view.

The third and final step required to complete our program of unification would be the bringing together of the co-ordinated work in mathematics and physics with similarly organized work in electrical engineering. The problem here is to make the student realize that he has not completed a course which can be left behind and forgotten, but rather that he is going forward into more advanced work which is a continuation of what has gone before requiring constant use of the principles he has learned. In order to carry this out with smoothness and harmony, instructors in each department should be thoroughly familiar with that portion of the work of the other department which lies close to the transition point. Even with the best co-operative spirit on the part of the faculties concerned it will take considerable time to plan such a program and effectually put it into operation. Many difficulties will exist in any institution, but no worth-while accomplishment in education is easy of attainment.

At Worcester Polytechnic Institute the previously outlined general plan is well underway for the electrical-engineering curriculum. The order in which the separate steps were undertaken has been somewhat different from that outlined herein. Our initial effort was devoted to co-ordinating thoroughly all of the undergraduate work given by the electrical-engineering department. The curriculum was completely revised four years ago in order that this work might go forward and the present senior class is the first to graduate under the new plan. There is unanimous agreement on the part of the department staff that the results show marked improvement in the students' comprehensive knowledge and general understanding.

Our second step is to co-ordinate the work of the physics and electrical-engineering departments. The problem has received much discussion and is being attacked with a fine spirit. Small groups composed of members of both departments are now working together on the many details. It is realized that if lasting good is to be accomplished much care and attention must be given to every step. In order to help the student appreciate the union between physics and electrical engineering the staff of the lattcr department will stress the importance of work in physics by frequently referring back to principles previously covered in physics courses, thus emphasizing the continuity. Similarly, members of the physics department will attempt further to awaken student interest by pointing out practical applications of the principles taught by them.

The objection may be raised that the amount of ground covered in a co-ordinated curriculum of this nature necessarily would be less. The answer is that the student's knowledge, understanding, and power of analysis would be increased. The measure of a college education never was, and never should be, the number of items covered in the separate courses of the curriculum. Many years ago the college with which I am associated adopted as a motto "Pauca Fideliter"—a few things faithfully. As we look forward to greater accomplishment in engineering education we must break down the barriers between the individual subjects so that the unity which exists so abundantly in nature shall permeate the separate parts and consolidate them into one complete whole.

Discussion

Royal W. Sorensen (California Institute of Technology, Pasadena): This symposium comprising the several papers has, indeed, been interesting and very instructive. It is so complete as to leave little that may be said in the way of conclusions; for, after all, all of us assembled here are not only engineers, but are professional teachers. We have, or should have, attained this professional standing by virtue of being men who can discern and devise our own ways of finding and overcoming students' impediments to learning. I don't agree with the ideas which some have presented, that the best teaching is always the one which makes learning easy. In fact the lifetime work of an engineer is that of doing new things. Invariably starting friction is greater than running friction. A future engineer should, therefore, while he is a student, learn to avoid being dismayed by heavy starting friction: that is he should, at least a part of the time, have the stimulus of unraveling problems in his own way even though that may be a very difficult one. Naturally as a teacher I try my best to present subject matter in such a way as to be readily understood; but I am not overly exercised if the students find the explanations difficult to understand. Will not these men, as they go out into practice after graduation, often be placed in the position of having to take instruction from men difficult to understand? And is it not a part of their business as students to learn how to interpret difficult and sometimes befogged instructions?

Reference has been made to poor instruction in high schools in science and mathematics. I am of the opinion that the present high-school graduates who enter our engineering schools with good entrance requirements, are today better prepared in science and mathematics than was the case a score of years back. Are we not prone to judge preparation by what we require rather than by actual standards of today as compared to those which prevailed a generation ago?

The California Institute of Technology has for several years recognized the expanding scope of engineering and has included a large amount of humanities in its courses. This fact combined with the expanding field of engineering technique has made it seem wise to grant for four years work the degree of bachelor of science in engineering, rather than specifying a particular branch of engineering. At the present time, by doing an additional year of work, our students may obtain the degree, master of science in some special branch of engineering, such as electrical, mechanical, or civil. Our meteorology and aeronautics departments, however, have deviated from this plan, and at the end of the fifth year are granting the degree, bachelor of science in aeronautical engineering or in meteorology as the case may be. My years of teaching experience have led me to look upon the four-year engineering courses as dual-purpose courses—the major purpose, perhaps, being that of a general education rather than a professional education, the professional education to be obtained by added years. With this thought in mind I do not advocate extending what may be known as the regular engineering courses to five-year or six-year courses, but I rather think it better to have our present terminal, four-year courses and add thereto such work as seems desirable for engineering preparation. Undoubtedly this means that an increasing number of men will spend at least five and preferably more than five years in college work in preparation for an engineering career. Such a program may introduce a dangerous situation if we encourage men to go on beyond the fifth year for a doctorate degree and use for courses leading to the doctorate degree, simply additional technical work of the type which has been given in our undergraduate courses. Men selected and encouraged to go on for doctorate degree courses should be limited to men who have outstanding analytical ability and who can without difficulty master advanced courses in mathematics and physics. In fact a large part of the graduate work leading to a doctorate degree for engineers should, in my opinion, be work done under the instruction of our ablest mathematicians and physicists.

My own experience with younger teachers, in fact even with men pursuing graduate work, used as teachers, has been most excellent. By carefully selecting the men who are to do the teaching and introducing them to the work first through laboratory courses and then in the classroom, we find the results equal to and frequently better than the results sometimes obtained by older teachers. This is no doubt due to the great enthusiasm of the young men who wish to try teaching, coupled with their recent contact as young undergraduates with the problems as they appear to the undergraduate.

Returning to the undergraduate courses, I question very much the advisability of including in the first four years of work, courses in transients, long transmission lines, and higher mathematics courses, because I think, for the large group of students, the first four years of work can best be spent in acquiring training in the simple fundamentals of science and engineering plus a considerable amount of general cultural education including such subjects as English, public speaking, history, economics, geology, etc. This thought, I suspect, agrees with Professor Malti, who suggests that we have all graduate students working for a doctorate degree take mathematics and physics as minors. With this I agree, except that the minor should comprise a large part of the graduate students' course work. Professor Malti seems to recommend the appointment of men who have just received their doctorate degrees as instructors. I think it would be much better to have such men enter industry for several years before being selected as instructors. Malti's comments regarding ability to do research as a prerequisite to teach, and regarding having the faculty keep in touch with industry are pertinent.

E. M. Strong (Cornell University, Ithaca, N. Y.): For something over ten years I have met nearly all of the students in engineering at Cornell as they come fresh from mathematics and physics to begin their study of electrical fundamentals in the sophomore or junior years. The place and nature of mathematics and physics in the engineering curriculum continuously interests me and I am appreciative of the cross section of current thought provided by this symposium.

I do not believe that we need here to sell the idea that mathematics and physics have in the electrical curriculum a place which is both important and steadily growing. Anyone really interested in the symposium is alive enough to be well aware of this. What he wants to know is "How can the faculty and curriculum best function to accomplish the admitted objective?"

I am surprised that no one has mentioned the economic factor in the situation because with few exceptions it is a most potent element in the whole program. Possibly there is something in the local atmosphere here which taboos recognition of economic restrictions. There are several angles to the economic problem. Let me mention two of outstanding importance:

1. The use of instructorships to subsidize graduate study and research.

2. Insufficient supervised computation.

In physics and mathematics particularly we find too many young men holding instructorships who have no interest in teaching except as it alleviates the immediate financial stress during their graduate study. Sometimes they seriously lack essential qualifications for teaching and especially for the teaching of the less mature student in the freshman and sophomore years who consequently functions as the "guinea pig" or the "goat" for these "instructors." Students during these years, more than at any time later, need the best *teaching* talent on the faculty. However good the curriculum and however good the administration it can produce results only in so far as the personnel which ultimately and *directly* contacts the student is competent not only in technical knowledge but also in ability to impart that knowledge and to inspire enthusiasm in the student. No man can do this except that he be genuinely interested in the student—he cannot do it if his mind is filled with graduate study or research to the exclusion of all else in the mad scramble for a degree by June 1.

The problem is largely an *economic* one for faculty and graduate student alike. I have no solution to offer.

Returning now to item number 2 (insufficient supervised computation). Engineering faculties are confronted with an increasing difficulty in obtaining from the public schools of the country any dependable foundation in mathematics—let alone physics or chemistry or habits of study and conduct. In college the departments of mathematics and physics lack facilities for building up the student in these deficiencies. One of the most successful methods employed in engineering instruction is the computing period which provides for the student a time and place to develop what we call engineering habits in the approach to problems and their solution—not only time and place but the sympathetic supervision which makes for more efficient work in the earlier years, in particular, than can be found in home study alone.

The problem is primarily an *economic* one to provide the required facilities of staff and room.

There is one other phase of the general problem about which I am moved to comment. I am fully in sympathy with any of the true co-operative movements which some of the authors have outlined for us. However, there are two kinds of "co-operation." One of these is not found defined under the word itself in Webster but is formally defined under "coercion." Engineering says to physics: "Your work isn't giving our students the foundation we need—will you co-operate in a revision?" "Yes, of course we'll co-operate." "Well, here's what we want—so and so and thus." "But I can't teach that, it doesn't do justice to physics." "Well, if you don't want to co-operate, we'll give it ourselves." Whether this work is then taught in engineering or in physics the result is deplorable.

Engineering does not go to English and dictate that only technical and scientific English be taught—nor to history for exclusively technical or scientific history. For the most part it hasn't had the face to go to language and insist on technical German or French, exclusively. If and when engineering in a university cannot co-operate with the rest of the university it might as well set up by itself as a technical school because any university affiliation is then not only unprofitable but possibly detrimental to its functioning.

I quite agree with Doctor Malti that these university departments of mathematics and physics must not be "bulldozed" into teaching their work according to rigorous engineering specifications. Let them have something of a cultural as well as the strict utilitarian purposes. Let them be supplemented or complemented by work in engineering, possibly concurrent in part, which will supply the point of view and the missing factors which no mathematician or physicist can be expected to provide in good faith with his own profession.

Again the question is an economic one—can it be done without increase in facilities?—can it be done in a four-year program?

M. L. Manning (Westinghouse Electric and Manufacturing Company, Sharon, Pa.): The paper by M. G. Malti is well written and offers among other things valuable suggestions for a proposed program of engineering teacher training.

I should like to contribute to this plan of engineering teacher training from the standpoint of the practicing engineer.

For selected teachers of engineering not only graduate work equivalent to a master of science degree, or better, with minors in mathematics and physics would be desirable but also following this work with at least a three- to four-year program of practical experience in industry leading to a doctor of philosophy degree. Since engineering is about three-fourths common sense a practical basis is necessary. This experience should be in design work followed by research and development problems. In this way a not-too-theoretical frame of mind is formulated but attention is also focused on the economics of the problem. The lack of this training is often so noticeable when former teachers of engineering enter into practical work. In setting up a problem the mathematical or physical beauty so engrosses the thought that all sight is lost of the practical side or how the results are to be obtained in the laboratory.

For an example, let us consider the response of a three-mesh transformer network to an impressed impulse voltage wave. Two thoughts are uppermost in the transformer design engineer's mind; namely, the initial and final or steady-state solutions. In the intricacy of the solution, it is easy to overlook these two important practical considerations. Because of the oversight results are sometimes expressed which lead to incorrect conclusions.

If the teacher were trained to recognize such important facts by experiencing them in industry, by actually designing and following the manufacture of electrical machinery, by obtaining a knowledge of the dollars and cents part of the picture, and by noting the attitude of industry toward these problems and toward educational work as a whole, a decided improvement in the quality and relationship to industry of teaching would be noted. An attempt should, of course, be made to make the equalization balanced; that is, not to lose sight of the educational as well as the industrial processes simultaneously.

It might be argued that such a program is difficult to fulfill, but it seems to the writer a staggered plan could be formulated. Due to the uneven keel of industry at times the absorption of this teacher training by industry would vary but over a period of time a program could be devised.

For an example, let us consider the graduate program of the Westinghouse Electric and Manufacturing Company as a suggested training course. The work is co-

ordinated at all plants. This means a student or engineer at the South Philadelphia works may receive graduate credit for a subject if he is transferred to the East Pittsburgh works, or to the Sharon works, etc. During the past year over 1,500 engineers and students participated in this plan and about 600 received graduate credit under the University of Pittsburgh—Westinghouse arrangement. A comprehensive program was also organized in the transformer division, the Sharon works. The average attendance for the courses was 92 per cent. The subjects included "differential equations for electrical engineers," "symmetrical components" and a well-organized transformer course. This latter course consisted of 31 sessions followed by comprehensive examinations. The classes were conducted by members of the transformer engineering department who were specialists on the particular topics studied. These topics were from one to five sessions in length. The course content follows:

1. Fundamentals (five*). The general differential equations, transformer vector diagrams, physics of the transformer, etc.
2. Practical distribution transformer design problems (two).
3. Fundamental considerations of reactance and stray losses (two).
4. Iron losses (two).
5. Magnetic forces (one).
6. Magnetic noise (one).
7. Radio interference (one).
8. Insulation (two).
9. Heating and cooling of transformers (two).
10. Condenser bushings (two).
11. Tap changers (two).
12. Inertaire equipment and oil filters (one).
13. Instrument transformers (one).
14. Distribution transformers (one).
15. Power transformers (one).
16. Constant-current regulators (one).
17. Preventive autoseries transformers (one).
18. Three-winding transformers (one).
19. Current-limiting reactors (one).
20. A-c welding transformers (one).

This course is mentioned only to suggest how other courses in electrical apparatus might be outlined for a program of engineering teacher training.

The method of presenting engineering problems as proposed in the paper by B. R. Teare, Jr., is commendable. The fact must not be overlooked that self-education at least in part is the only practicable way in which most students can acquire higher mathematics and physics. Most students fail to grasp the concept of expressing physical relations in mathematical form. The technical student often finds, upon entering a class in engineering, that he has to deal with mathematics under a new form. The particular engineering subject he is studying must be translated into mathematical terms and this causes difficulty. The sense of perspective is often lacking. This can be developed as the student becomes more mature provided he makes actual use of mathematics.

Skill in the use of mathmatics is the really essential thing. Use of arithmetic with algebra, perhaps, or a simple diagram often leads to more satisfactory results than others secured through elaborate processes involving lengthy equations and complicated operations. In the latter, errors are apt to occur, and the commonsense part of the problem is likely to be overlooked. Assumptions may be made to facilitate calculations which are physically unwarranted, as one loses sight of the physical problems in the intricacy of the mathematical solution. Abstract mathematical studies, if pursued as a kind of intellectual exercise, may produce a pure mathematician, but these studies may unfit a man for practical engineering. A tool expert is not necessarily a successful manufacturer, nor is a mathematician necessarily an engineer.

*Number of sessions.

Mathematics is used in engineering to express the quantitative relations of natural phenomena. The mathematician delights in the relations. He may divorce them from the phenomena and give them abstract expression. The engineer is concerned with the natural phenomena and demands the physical conception. The medium of expressing these relations is of secondary consequence.

In summarizing, the engineer is concerned with applied mathematics. The ability to state a problem, to recognize the elements which enter into it; to see the whole problem without overlooking some important factor; to use good judgement as to the reliability or accuracy of the data or measurements which are involved and the ability to interpret the result; to recognize its physical significance; to get a commonsense perspective of its meaning and the consequences which may follow; to note the bearing of the various data on the final result, such abilities as these are of higher order than the ability to take a stated problem and work out the answer. It is this sort of judgment and insight which makes mathematics useful.

We should emphasize not the subject matter nor the students but the method of teaching. Aside from the imparting of knowledge and technical ability, the teaching of the use of mathematics and physics in engineering problems gives opportunity for training in the use of logical methods, and in the drawing of intelligent conclusions from unorganized data which will make efficient men, whether they follow pure engineering or semitechnical, or business pursuits. Such teaching does not come from the textbook, it comes from the teacher. He must be in sympathy with engineering work and have a just appreciation of its problems and its methods. He must be imbued with the spirit and the ideals of the engineer.

M. S. Coover (Iowa State College, Ames): Professor Curry has presented an admirable discussion on the means of co-ordinating the three major component parts of training for engineers and more particularly electrical engineers. His paper reads very much as I would hope that mine might read if I were called upon to expand the objectives as they have been written just recently for the curriculum in electrical engineering at the Iowa State College.

The problem that concerns me most is the crowding that seems to be so necessary in order to stay within a normal four-year program. The subject matter of a majority of courses is assigned to the student in such rapid sequence that even the better-than-average student finds it difficult to make a really satisfying useful assimilation either from his own viewpoint or that of his instructor. This problem may not be so serious for these institutions who have the opportunity to hand pick their students, but it is a problem the solution of which is not so easy for publicly supported institutions.

At the college which I represent there is a growing tendency on the part of the truly conscientious student to realize the value of the best training that he can get if he is to reach a satisfying place in this highly competitive social and scientific age. Accordingly, we find more engineering students taking advantage of our summer school offerings in order to lighten the number of credit hours during the winter months, thereby making available more time for the remaining courses. By this process he is spreading his training and mental efforts over the equivalent of five academic years within the space of four calendar years.

If we as teachers are intending to give to the student the best that it is possible to give him we should not only make every effort closely to co-ordinate our own work within a given department but as Curry points out, maintain a closer personal relationship among the several departments concerned.

Malti has done a good job of stating the processes involved in the handling of engineering problems from the purely technical viewpoint.

He makes the statement that something seems to be wrong either in our teaching of mathematics and physics to engineers or in the proper co-ordination of these subjects with engineering courses or both. What serious-minded student, teacher, or engineer has not entertained similar thoughts from time to time?

No doubt some of the reasons for these undesirable situations are present in various degrees in most educational institutions. Some of the remedies which Malti suggests are good. Physicists and mathematicians cannot help but improve their teaching of engineering students if they will take a closer interest in engineering and engineers. Since mathematics and physics combine to form the foundation upon which the engineering educational structure is to be built, co-operation among those concerned is essential if the structure is to be useful.

The desirability of competent teachers with an adequate education cannot be disputed. However, a man with an armful of degrees is not necessarily the best teacher. The individual is more likely to be a good teacher if he has had a reasonable amount of responsible commercial or industrial seasoning. If he has demonstrated his ability, he is more likely to know his subject better, to appreciate its significance, and therefore, more likely to be enthusiastic and inspiring, thus developing and stimulating the student's intellectual curiosity. Simply to specify a certain type of academic training for the teacher in order to qualify for an appointment is most likely to lead to what has been cited as one of the prevalent ills. If, for the sake of argument, it is granted that we do not now have good engineering teachers, how can the present teachers educate better ones along the lines suggested?

On the matter of co-operation between and among the departments of physics,

mathematics, and electrical engineering, I venture with apologies to cite what we are doing at the Iowa State College for the reason that I am not familiar with what is being done along the same line at other institutions, but in so far as I am informed it is with but one exception practical only at those institutions where say the departments of physics and electrical engineering are under one and the same headship. At the Iowa State College, each of the three departments under discussion is administered separately. The instructor in the mathematics department who is assigned to the instruction of electrical-engineering students in differential equations teaches one section of junior electrical-engineering students in a-c circuits in the electrical-engineering department; exchanging with one of our own staff members who teaches one section of differential equations to engineering students in the mathematics department. It goes without saying that close co-ordination thus becomes a requisite. A similar arrangement is practiced between the departments of physics and mathematics and is being developed between the departments of physics and electrical engineering, thus closing the triangle.

On another point, I believe that physics and mathematics are chosen almost invariably as minors for work leading to the degree of doctor of philosophy with a major in engineering.

Albert A. Nims (Newark College of Engineering, Newark, N. J.): The co-ordination about which we are talking is well illustrated by the papers themselves. Professor Bryant refers to the lack of co-ordination in his student days among the terms and methods used to explain the quantitative relationships in electric circuits, and the performance of the different varieties of electrical machines. The present situation is reflected by Professor Curry, who refers to "training the student . . . . to search for the fundamental principles upon which a statement of the problem may be formulated . . . . since subsequent engineering courses will utilize the same principles." It might well be said that the same search should be constantly in the mind of every teacher who wishes to increase his professional effectiveness.

One of the most promising ways of increasing the efficiency of our teaching methods is so to organize our subject matter that the number of new concepts to be mastered is a minimum, and the usefulness and applicability of each is a maximum. Some indication that this search for common denominators is making progress is found in Professor Teare's references to "the analogous behavior of electric circuits, mechanical systems, and heat conduction systems, expressed in exactly similar equations," and "to the broad analogy between the space fields of electrostatics, magnetostatics, gravitation, thermal and electric conduction, and fluid flow, described by similar vector equations and identical field maps."

Not too much can be expected of this ideal simplification, however. Professor Strong has referred to the practical considerations which intrude themselves into every theoretical plan, no matter how ideal, and has mentioned the economic factor. Professors Bryant and Coover have referred to the time factor which creates a continual pressure for increased efficiency in presentation of subject matter. Another practical consideration is the mind of the student himself, which sets a practical limit to the process of searching for common denominators.

Highly generalized statements are of little use as an initial approach to the phenomena of electrical engineering. The increments of knowledge by which a new subject is mastered are limited in size. The assimilable increments vary in size with each individual, but, with our mass production methods, some working average must be used. Teaching efficiency is likely to be a maximum when the number of fundamental concepts is such that each can be acquired in the minimum number of practical steps, and each will be of the widest use after it has been mastered.

Professor Morgan has pointed out that instruction is more efficient when "laboratory and classroom courses do not exist separately; each division of the work should receive investigation in the laboratory at the same time that it is being discussed in the class room." Professor Strong has referred to the effectiveness of computation exercises for driving home fundamental relationships in the minds of the students. Computation might well be made a third approach, co-ordinate with classroom discussion and laboratory exercises. "Slide-rule pushing" and "graph plotting," when properly organized and motivated, can be potent tools with which the student can reveal to himself relationships that otherwise he might not grasp. One of the comments most frequently made about the course in winding specification and performance computation offered at the Newark College of Engineering under the name of electric machine design is to the effect that "you certainly know what goes on inside a generator after you have figured out one of those designs."

Computation is a kind of laboratory work that requires very inexpensive equipment. In fact, it is about the only kind of laboratory exercise one can have in a mathematics course. At the Newark College of Engineering at least one computation exercise per week is scheduled in the second-year calculus course. The project method, based almost entirely on computation, is the procedure adopted for studies of networks, and of transient phenomena in the junior year.

The one-semester course in transients is the outgrowth of a brief theoretical discussion given in preparation for some laboratory exercises. It naturally involves considerable work with differential equations of a few varieties. The interest aroused by this course, together with that generated by the discussion of tensor analysis in the technical press, has resulted in the scheduling of two optional after-hour courses for the juniors. One deals with differential equations for one semester, and the other with vector analysis for an equal length of time. The optional and after-hour features operate automatically to select the abler students. The courses are conducted by the head of the mathematics department, who makes no claim to being an engineer. The method of presentation involves a minimum of manipulative theory and a maximum of applications, such as engineers are constantly meeting. The results of these courses seem to be twofold: an increase of mathematical interest and understanding on the part of the students who take them, and an increase of engineering interest and understanding on the part of the teacher.

Wm. A. Del Mar (Habirshaw Cable and Wire Corporation, Yonkers, N. Y.): Speaking as an engineer to an assembly composed chiefly of teachers, I can pay my compliments to the teachers of mathematics and say that they have not sinned so much as been sinned against in being forced to expend their energies on refractory material.

It is quite possible that a genius of a teacher may be able to make a mathematician of almost anyone, given ample time to work with him, but in college education we are concerned with mass production and a time must assuredly be reached when the teacher realizes that certain students are by nature mathematically inept, as far as mass education is concerned. Such men should not be forced to drag their classes and develop inferiority complexes by being either flunked or allowed to proceed with nothing but a memorized knowledge of data and standard processes.

It should not be difficult to deflect into other activities men whose minds run against a blank wall in trying to express physical problems in mathematical terms.

Is it not the failure to do this that gave rise to the need of this symposium?

W. A. Curry: Discussion has added a number of valuable suggestions and viewpoints on this matter of co-ordination and confirms the importance and interest which this problem holds for all who are concerned with electrical-engineering curricula. It would appear that we may attempt to achieve this objective in a variety of ways, and this diversity indicates that there is no single, royal road to its realization. Only by continued vigilance can an effective co-ordination be attained and maintained through the changing years.

M. G. Malti: I should like very much to endorse Sorensen's ideas regarding contact with industry. I have had the good fortune of being a consultant for a manufacturing concern over a period of several years and the pleasure and stimulus which this contact with industry has given me have been reflected both in my teaching and writings. Every trip I made to the plant and every summer I spent in it have given me more insight into the practical applications of my specialty which I have conveyed to my students. It is extremely desirable, therefore, that graduate students keep in constant touch with industry either through consultation or through regular employment. Whether such men would return to teach *as instructors* after they have been in industry, for some time, is questionable.

Strong's stress on the economic problem is misplaced. The fact that a graduate student takes an assistantship to enable him to do graduate work does not necessarily imply that he makes a poor teacher. Nor is it true that a researcher is invariably absorbed by his research to the exclusion of

everything else. I agree that instances do occur where a graduate student has turned out to be a poor teacher. This, however, is a fault of the individual concerned rather than of the system of using graduate students as assistants. As to computations, I am positively in favor of them and have used them in connection with my courses. But I attempt to make my computation not "slide-rule" or "formula-substitution" problems but rather problems which stimulate thought. Computing periods should, in my opinion, be periods in which the habit of straight thinking is required under competent supervision.

Nims seems to favor "slide-rule pushing" and "graph plotting" as showing the student "relationships which he otherwise might not grasp." I am sure the "graphs" themselves do reveal such relationships but I question whether the actual plotting of these graphs does! In order to illustrate what I mean let us assume that one laboratory course is run by two different instructors as follows:

Instructor A requires his students to run the equipment, take data, and when the experiment is over gives his instructions as follows:

(*a*) Compute only one point on each curve or perhaps only one curve, thus reducing slide-rule pushing to a minimum.

(*b*) Blue prints of all curves are given to each student. You *do not have to plot any curves* but!

(*c*) Give a complete and adequate discussion of the why, how, wherefore, of all the results that the curves reveal.

(*d*) Answer the following pertinent questions (which require thinking) regarding the results of your experiment.

This is the instructor who does not care to have his student waste time on curve plotting and slide-rule pushing. He would rather have them use their time in forming correct habits of thought.

Instructor B requires his students to run the equipment, take data, and when the experiment is over gives his instructions as follows:

(*a*) Compute *all points* on each curve (maximum slide-rule pushing).

(*b*) Make neat plots of *all curves* using india ink (maximum curve plotting).

(*c*) Discuss curves (by this he generally means say that this curve runs this way and that curve runs that way, which of course is obvious from the curve itself).

This is the instructor who requires "curve plotting" and "slide-rule pushing" and is the preponderant type in our engineering colleges.

Now I ask who turns out better engineers, instructor *A* or instructor *B*?

Del Mar puts his finger on the right spot when he states that our present plight is due to mass education in engineering. Now it so happens that other professions have solved this problem of mass education by limiting enrollment. This is true of the medical, dental, and legal professions. Engineering as a profession has, so far, not seen fit to take this step which, in my opinion, is the only solution to the problem.

Coover raises the question of how the present teachers can educate better ones if they are not so good themselves. My answer is that Coover begs the question. I neither did condemn nor even had the intention of condemning *all* engineering teachers. Thank God there are high-grade teachers scattered throughout this land. It is these who would and could educate better ones along the lines suggested.

Manning and I are in full agreement. The value of co-operation between industry and the universities is unquestionable. They both have something to offer to each other and a mutual exchange is extremely desirable. I should like to see a plan instituted whereby a large number of engineering teachers throughout the country are afforded a chance to spend their summers in industrial concerns. I also commend Manning's statements that mathematics and physics are valuable to the engineer not perhaps so much because of their subject matter but because of the training they afford him in logical reasoning and in correct processes of thought.

Self-Excitation of Induction Motors

By C. F. WAGNER
MEMBER AIEE

Synopsis: It has been known for some time that an induction machine whose rotor is driven mechanically may become self-excited if capacitors are connected across its terminals. The present paper is concerned with the predetermination of the machine characteristics when operating under such conditions. The frequency of excitation is very close to the synchronous frequency corresponding to the speed of the rotor. The voltage to which the machine will excite is dependent upon its no-load excitation characteristics at that frequency, the criterion to be satisfied being that the lagging volt-amperes of excitation equal the leading volt-amperes of the capacitors.

Under load, similar criteria must be satisfied. Voltage conditions are determined by a cut-and-try solution such that the summation of reactive volt-amperes equals zero. The slip is then obtained from the relation that the summation of the real power equals zero. These relations have been applied to various types of loads, such as pure resistance and inductive resistance, single-phase and three-phase and also to induction-motor load. Excellent checks between test and calculated results have been obtained.

THE general impression appears to exist that for an induction machine to operate either as a motor or as a generator a source of alternating potential is always necessary in order to supply the excitation requirements. Such is not the case, for under certain conditions, an induction machine may supply power as a generator without a source of alternating potential, the magnetizing current being supplied by static capacitors. It is the purpose of this paper to discuss the circumstances under which such operation becomes possible.

The fact that such operation is possible has been known for some time, but very little has been written upon the subject until recently. The reason for this paucity of papers and articles lies in the relatively minor practical importance of the subject. However, the increased use during the past few years, of capacitors for power-factor correction, has placed a new aspect upon this problem. If the power supply to an induction motor is disconnected, the inertia of the connected rotating load tends to continue the rotation of the armature. The extent to which this occurs is dependent upon the nature of the load and in certain cases the armature may continue to rotate for seconds or minutes. In addition, applications are known in which gas or gasoline motors are connected to the same shaft with the induction motor and the utilization device, so that, in the event of the removal of the electric-power source, the armature can actually increase in speed and remain at the increased speed until manual readjustments are made. With capacitors connected across the terminals of induction machines which have been disconnected from the electrical source and in which the armature continues to rotate, the value to which the terminal voltage will rise due to self-excitation is dependent upon the speed, value of the capacitor, and load. With the regulatory function of the power source removed the terminal voltage may rise to dangerously high voltages—dangerous with regard to human life or dangerous with regard to insulation breakdown. Parallel-connected lights might also burn out with but a nominal increase in voltage. It may be seen, therefore,

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1. For all numbered references, see list at end of paper.

that this problem has been removed from one of purely academic interest to one of practical importance.

In 1935, Bassett and Potter[1] presented test results showing the performance of generators under capacitive and combinations of resistance and capacitive loading. The present article considers similar problems and further shows that the performance under such conditions, including both balanced and unbalanced operation, can be precalculated quite accurately.

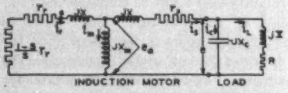

Figure 1. Equivalent circuit of induction generator with three-phase load of capacitors $-jx_c$ in parallel with induction load $R + jX$

With known conditions the characteristics of the machine can be predicted by the methods presented here.

General Considerations

The conventional equivalent diagram of the induction motor will be used with the exception that the magnetizing branch will not be regarded as constant but must vary in the manner dictated by the saturation characteristics of the particular machine. This circuit is shown in figure 1 for one phase. The symbols will have the following significance:

- r_s = Stator resistance in ohms per phase to neutral
- r_r = Rotor resistance in ohms per phase to neutral
- x = Stator and rotor leakage reactances in ohms per phase to neutral
- x_m = Reactance of branch representing magnetizing current in ohms per phase to neutral
- s = Slip expressed as a fraction of synchronous speed

The slip is referred to the frequency of the stator voltages and currents and, when operating as an induction generator, is, of course, negative.

The general considerations which will be applied in determining the solutions are that the summation of the real power and the summation of the reactive volt-amperes throughout the entire circuit, including that of the load, must each equal zero. Because of the presence of saturation phenomenon, resort will be had to a graphical or a cut-and-try method of solution.

Most of the tests which are described in what follows were made on a 15-horsepower, three-phase 60-cycle 220-volt 1,770-rpm type *CS* Westinghouse motor of conventional design. The constants, obtained from test data, are

- r_s = 0.151 ohm per phase to neutral
- r_r = 0.145 ohm per phase to neutral
- x = 0.394 ohm per phase to neutral
- x_m (air-gap line) = 19.8 ohms per phase to neutral

The no-load saturation curve is given in figure 2. The lower portion of this curve, indicated by circles, was obtained by impressing a three-phase alternating voltage to the machine terminals and varying the speed by means of a connected d-c motor so that the power input from the a-c end was zero.

No-Load Excitation

A three-phase bank of static condensers was connected (without the a-c supply) across the terminals of the machine and the rotor driven at a speed corresponding to normal synchronous speed by means of the d-c motor. Since only the losses of the machine must be supplied, the quantity, $\frac{1-s}{s} r_r i_r^2$ (figure 1) which represents the shaft input, will be very small. This condition requires that s be very small and consequently that $\frac{1-s}{s} r_r$ be large and i_r small. The equivalent network for this operating condition for all practical purposes reduces to that shown in figure 3 in which r_s of figure 1 has also been neglected. Because s is small the generated frequency corresponds to that of the shaft which in this case is normal frequency. Upon varying the magnitude of the capacitors the test points, indicated by crosses in figure 2, were obtained, extending the no-load excitation curve to more than ten times normal excitation current. It will be observed that over the portion of the range for which the data overlap, the test data checks with that obtained by the application of an alternating voltage. Referring to the equivalent circuit of figure 3 it may be seen that the ratio $\frac{e}{i_m}$ for any point on the no-load excitation curve must equal $(x_m + x)$ or x_c. In order that the reactive kilovolt-amperes sum up to zero, x_c must equal $(x_m + x)$. Thus the slope of a straight line drawn from the origin of the curve of figure 2 to any point on the curve gives the capacitive reactance of the capacitor required to produce that voltage at no load. As the condenser capacity decreases the slope representing its capacitive reactance increases and the terminal voltage decreases. When finally the slope equals the air-gap line, an infinite number of solutions are possible. Beyond this point the machine is inoperative. Therefore, there exists a certain minimum amount of capacitors which will still produce self-excitation. In this regard the induction generator performs in a manner quite analogous to a shunt-excited d-c generator.

In what follows it will be necessary to know the volt-ampere characteristics of the x_m branch alone. This is obtained from the dotted line in figure 2 by subtracting the xi drop giving the curve shown by the full line and marked "air-gap voltage."

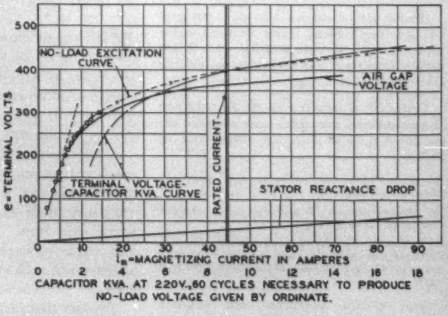

Figure 2. No-load saturation curve of 15-horsepower 220-volt 60-cycle induction motor

o = motor connected to a-c source

x = motor excited through capacitors

A further demonstration of the truth of the above theory is offered by the manner in which the terminal voltage changes with change in frequency. The full lines in the insert of figure 4 show the magnetizing characteristic and the capacitor characteristics for normal frequency. As the frequency is increased the terminal voltage for a given magnetizing current increases proportionately with the frequency. On the other hand, the capacitor current varies inversely proportional

to the frequency. These characteristics are shown by the dotted lines for an increase in frequency of about 20 per cent. The new terminal voltage is then given by the intersection of the dotted lines. The comparison between test and calculated results using this method is shown by the circles and crosses in figure 4, which indicate a very close agreement.

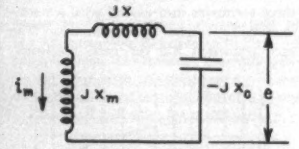

Figure 3. Equivalent single-line diagram for no-load excitation condition

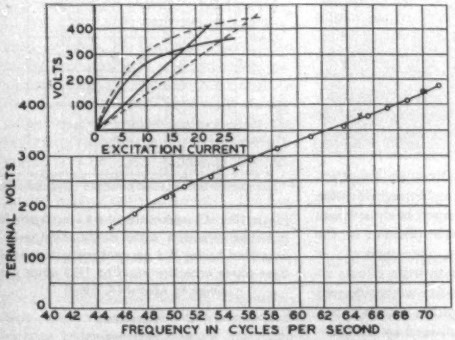

Figure 4. Effect of change in frequency

No load—constant shunt capacitor = 10.6 kva at 60 cycles

o = test points

x = calculated points

In order to provide a better quantitative perspective of the values involved, the dashed line in figure 2 was calculated. This curve gives the terminal voltage as a function of the kilovolt-amperes of the capacitors at normal frequency and voltage. It will be seen that for a capacitor whose kilovolt-amperes is equal numerically to the horsepower rating of the machine the terminal voltage reaches a value equal to twice normal. This will vary within limits for different motors, depending upon their excitation characteristics.

Three-Phase Impedance Loading

To determine the regulation characteristics under polyphase conditions, the induction generator was loaded with three resistance racks, which upon measurement were found to have 8.3-per cent reactance at 60 cycles. With a constant capacitor bank the load was changed keeping the load frequency constant with the result shown in figure 5. The circuit under consideration is shown complete in figure 1. To calculate the performance while keeping the capacitor fixed the following steps are involved. An arbitrary value of R and its corresponding value of X are chosen for which it is desired to determine the terminal voltage, e. Estimate the value of e. This fixes i_L and i_c. The current i_s is the sum of i_r and i_L. Knowing i_s the drop through $r_s + jx$ is found which determines e_a. The magnetizing current i_m is obtained from the full line of figure 2. And, finally, i_r is the sum of i_m and i_s. At this point all the currents are determined for the estimated values of e. All of those operations are, of course, vector operations. If the estimated value of e is the solution the following relation should be satisfied.

$$Xi_L^2 + xi_s^2 + e_a i_m + xi_r^2 - x_c i_c^2 = 0 \quad (1)$$

If, however, this summation is not satisfied a different value of e should be tried.

The comparisons between the test and calculated results for two values of capacitors are shown in figure 5.

The slip for this particular value of R is determined by summing up the power quantities for the solution obtained from the summation of reactive volt-amperes and equating this sum to zero. No cut-and-try method is necessary. Thus

$$\frac{1-s}{s} r_r i_r^2 + r_r i_r^2 + r_s i_s^2 + i_L^2 R = 0$$

or, combining the first two terms and solving

$$s = -\frac{r_r i_r^2}{r_s i_s^2 + i_L^2 R} \quad (2)$$

Values of s obtained by this method are shown in figure 5.

Calculated curves for pure resistance load and for the same capacitors are plotted in figure 6. It will be observed that the regulation is very much better. The series reactance in the load for the former case, although only 8.3 per cent, exerted considerable influence upon the terminal voltage.

An interesting condition exists for the range of operation indicated by the dotted lines in figure 6. Note that for this range there is no appreciable saturation so that x_m can be represented by a constant. It is possible, therefore, to determine the impedance of all that portion of the cir-

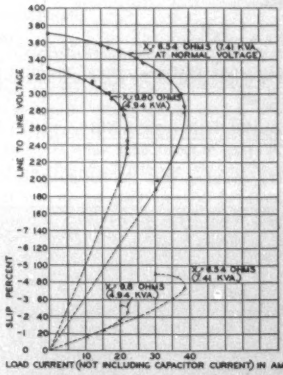
X_c 8.54 OHMS (7.41 KVA AT NORMAL VOLTAGE)
X_c 9.80 OHMS (4.94 KVA)
X_c 9.8 OHMS (4.94 KVA)
X_c 8.54 OHMS (7.41 KVA)
LINE TO LINE VOLTAGE
SLIP PERCENT
LOAD CURRENT (NOT INCLUDING CAPACITOR CURRENT) IN AMP.

Figure 5. Characteristics of a 15-horsepower induction generator under three-phase resistance load having 8.3 per cent reactance

x = calculated points

o = experimental results

——— = terminal voltage

– – – – = slip

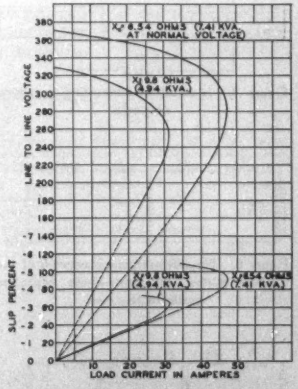
X_c 8.54 OHMS (7.41 KVA AT NORMAL VOLTAGE)
X_c 9.8 OHMS (4.94 KVA)
X_c 9.8 OHMS (4.94 KVA)
X_c 8.54 OHMS (7.41 KVA)
LINE TO LINE VOLTAGE
SLIP PERCENT
LOAD CURRENT IN AMPERES

Figure 6. Calculated characteristics of a 15-horsepower induction generator under three-phase resistance load

——— = terminal voltage

— — — = slip

cuit in figure 1 which lies to the right of a. A solution exists when this impedance is purely real, there being no imaginary part. Since for pure resistance load of figure 6, X is zero, then R and $-jx_c$ in parallel become $\frac{-jx_cR}{R-jx_c}$ which will be designated by $R' + jX'$, in which

$$R' = \frac{x_c^2 R}{R^2 + x_c^2} \tag{3}$$

and

$$X' = \frac{x_c R^2}{R^2 + x_c^2} \tag{4}$$

The impedance to the right of a then becomes

$$\frac{jx_m((R' + r_s) + j(x + X'))}{(R' + r_s) + j(x + X' + x_m)} + jx$$

The condition that the imaginary component of this expression equals zero, results in the following equation:

$$(x + X' + x_m)[x_m(x + X') + x(x + X' + x_m)] + (R' + r_s)(x_m + x) = 0 \tag{5}$$

Upon substituting (3) and (4) into (5), a fourth degree equation in R results, which permits the determination of R. The quantity R is equal to $\frac{1}{\sqrt{3}}$ times the slope of the dotted lines in figure 6. The significance of this expression is that there are an infinitely large number of solutions for the terminal voltage when R has the value

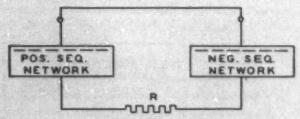

Figure 7. Method of connecting sequence networks

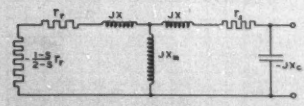

Figure 8. Negative-sequence network of induction motor with three-phase capacitor across its terminals

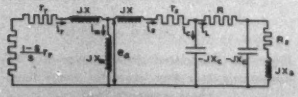

Figure 9. Equivalent circuit for induction generator and three-phase capacitor loaded single-phase by resistance R

satisfied by this equation. Actual operation is impossible at any of these values as an attempt to operate on the straight part of the curve results in instability. For values of R slightly smaller than this critical value the machine loses voltage, is unstable. A self-excited induction machine cannot, therefore, supply a sustained short-circuit current. A similar expression can also be derived for the dotted lines in figure 5, the slope of which represents the limiting ratio of $\frac{\sqrt{3}\,e}{\sqrt{R^2+X^2}}$ which still permits operation as a generator.

Single-Phase Impedance Loading

For this case let it be assumed that a resistance R is placed across phases b and c of the induction generator, the capacitors still being connected across all three phases. This is analogous to the short-circuit of a three-phase system through a resistance R, a case treated frequently in the literature.[2] For this case the positive- and negative-sequence networks are connected together as shown in figure 7. The actual current through the resistor R is $\sqrt{3}$ times the positive- or negative-sequence current flowing through R in the diagram. This procedure tacitly assumes the justifiability of superposition in the presence of saturation phenomenon. It will be assumed that saturation effects influence only the positive-sequence network and not the negative-sequence network. The checks obtained by comparison between the calculated and test values justify these assumptions. The positive-sequence network of the machine is the same as has been considered previously in this paper and the negative-sequence network, with the exception of the capacitors, has been treated previously in the literature.[3] This network is reproduced in figure 8. Since s is usually small, a good approximation is to assume s equal to zero and to combine r_r and $-\frac{1-s}{2-s}r_r$ making the sum equal $\frac{r_r}{s}$. It will be assumed that x_m can be replaced by a constant term determined by the air-gap line. It is thus possible to replace the negative-sequence network of figure 8 by a simple impedance independent of saturation and slip. The resultant combined network for the positive- and negative-sequence is therefore that shown in figure 9; $R_3 + jX_3$ is the impedance to which the network of figure 8 has been reduced neglecting the impedance of the capacitors $-jx_c$. The current in the load is equal to $\sqrt{3}$ times the current in R and armature or load voltage is $\sqrt{3}$ times the voltage across R.

If the load is an impedance instead of a pure resistance, it is only necessary to replace R by $R + jX$ where X represents the reactance of the load. Tests and calculations upon the foregoing basis have been made on the previously used induction motor excited with capacitors across three terminals and loaded with a resistance rack across two terminals. The rack possessed 8.3 per cent reactance.

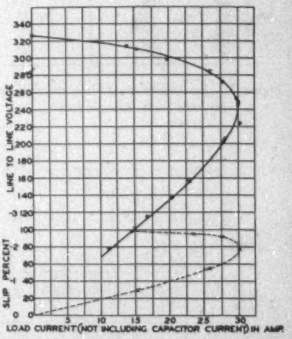

Figure 10. Characteristics of a 15-horsepower induction generator under single-phase resistance load having 8.3 per cent reactance and a three-phase capacitor equal to 10.3 ohms per phase to neutral (4.7 kva)

x = calculated
o = experimental
——— = terminal voltage
- - - - - = slip

The results of these tests and calculations are plotted in figure 10, which shows very close agreement.

If a capacitor is connected across the load only then the two capacitors $-jx_c$ of figure 9 must be removed and a single capacitor having the impedance of the actual capacitor must be connected across the load impedance.

Load Characteristics

Under certain conditions an induction generator driven by an engine or other equivalent motive power might have connected to it other induction machines which had also been connected to the source of supply. At the time of failure of the a-c source of supply the engine-connected induction motor tends to drive the other induction machines at a frequency determined by the speed characteristics of the motive power and at a

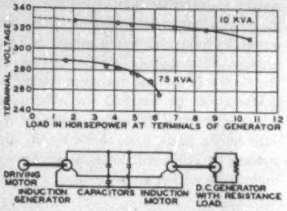

Figure 11. Self-excitation characteristics of two 15-horsepower induction motors, one of which is driven as an induction generator feeding the other as an induction motor. Figures on curves represent capacitor kilovolt-amperes at 220 volts, 60 cycles

voltage determined by the shunt-connected condensers. In figure 11 is shown a test setup to determine the characteristics of an induction motor when operating under such conditions. The setup consists of two of the above-mentioned motor-generator sets, the induction machines having the characteristics of those described previously. One of the d-c machines acted as a motor to drive one of the induction machines as an induction generator and the other induction machine drove the second d-c machine which was loaded upon a resistance rack. The two induction motors were connected in parallel and a bank of condensers connected across their terminals. Under this type of operation, theory dictates that the capacitors supply not only the excitation requirements of both induction motors but also the leakage reactance volt-amperes of the two machines. The curves of this figure show the characteristics at 60 cycles for constant values of capacitors as the load is increased on the induction generator. The no-load values of the voltage correspond to the values obtained previously for the no-load condition. It will be observed that the upper of these curves is much flatter than the lower one. The reason for this is apparent when it is considered that as the load is increased, the increase in leakage reactance volt-amperes of the machine must be supplied from the decrease in volt-amperes required by the excitation. At the higher voltages produced by the larger condenser capacity the machine is operating at a higher saturation and, therefore, more reactive volt-amperes is released for a given change in excitation voltage.

For the particular values of condenser capacity used in these tests, it was necessary to bring the driven induction motor up to speed by its d-c machine in order to make the sets excite themselves and carry load. However, at the no-load condition discussed previously, the machine came up to voltage very rapidly provided there was sufficient capacitor kilovolt-amperes to provide the excitation. In the loaded case, the capacitor kilovolt-amperes was too low to supply both the excitation requirements and the leakage reactance volt-amperes of the machine. Subsequent tests in which a five-horsepower 550-volt induction motor was used for the load both sets were excited very nicely by either bringing the two machines up to speed simultaneously by the one driving motor or by first exciting the induction generator and then connecting the five-horsepower machine. The question merely resolves itself into one of whether a given capacitor can supply both the excitation kilovolt-amperes of the generator and the starting lagging kilovolt-amperes required by the stationary motor.

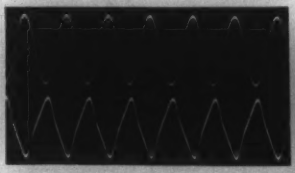

Figure 12. Wave forms for a 15-horsepower, 220-volt three-phase induction motor operating at no load and excited by a five-kilovolt-ampere static capacitor

Upper curve—terminal-to-terminal voltage = 320.4 volts

Lower curve—armature current = 18.3 amperes

Wave Shape

Oscillograms of terminal voltage under either no load (figure 12) or load (figure 13) indicate a very close approximation to sine wave. The current wave forms are distorted to some extent.

Conclusion

Calculations have been made for several conditions, both at no load and under load and the results agree closely with the test results. These checks include both balanced and unbalanced operating conditions. It is felt from this that, given the motor characteristics, the self-excitation effects can be predicted in advance to the same degree of accuracy as that of the information.

Figure 13. Wave forms for a 15-horsepower 220-volt three-phase loaded induction motor excited by static capacitors

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1. Capacitive Excitation for Induction Generators, E. D. Bassett and F. M. Potter. Electrical Engineering (AIEE Transactions), May, 1935, page 540.

2. Symmetrical Components (a book), C. F. Wagner and R. D. Evans. Page 43.

3. Symmetrical Components (a book), C. F. Wagner and R. D. Evans. Page 349.

Use of Bismuth-Bridge Magnetic Fluxmeter for A-C Fields

By G. S. SMITH
MEMBER AIEE

THE methods most often used for the measurement of d-c, a-c, and transient magnetic fields depend upon one fundamental law: that a voltage is generated in a conductor cutting lines of magnetic flux. However, for each of these fields the apparatus and procedure are entirely different. Perhaps the greatest difficulty arises in the study of a magnetic field under transient conditions, since the resulting voltage oscillogram is a composite of several components having more or less intricate phase relations. Thus the actual magnetic-field values or changes are rather difficult to obtain. A single instrument, adapted for use in any of the three fields, would be very desirable. With this object in view, the following report describes the work done in attempting to use, for the measurement of a-c and transient magnetic fields, an instrument previously proposed for use only in the d-c field.

Analysis of Problem

In a previous paper[1] an instrument for measuring d-c magnetic fields was described which gives a continuous and steady reading when placed in the field to be measured. Its operation depends upon the change in electrical resistance bismuth exhibits when placed in a magnetic field. Two bismuth resistors are placed in the opposite arms of a wheatstone bridge and in zero magnetic field the bridge is accurately balanced by using some ordinary resistance material in the remaining arms. When placed in a magnetic field the bridge is unbalanced by an amount depending upon the effect of that field upon the bismuth resistance. Thus the current or voltage due to this unbalance can be calibrated directly in terms of the magnetic field density. To avoid changes in the zero setting of the meter, due to temperature variation, all resistors in the bridge are adjusted to have the same temperature resistance change.

During the investigation covered by the previous paper the meter was tried in an a-c magnetic field and a definite reading was obtained, but no quantitative tests were attempted at that time. By substituting an oscillograph vibrator

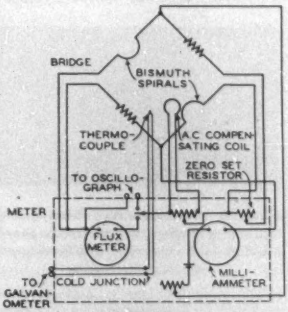

Figure 1. Wiring diagram for magnetic fluxmeter and bridge

in the fluxmeter position in figure 1, the oscillogram shown in figure 2 was obtained, indicating that the meter could also be adapted to transient-flux measurements. This report describes the work done in altering the design of the same instrument so that it can be calibrated for use in a-c magnetic fields, or used for transient-flux investigations.

The fluxmeter current shown by *A* in figure 2 is a composite of two current components a portion of which has been sketched in on the oscillogram. Although they have not been drawn to exact scale, it can be seen that the pulsating component which remains positive at all times represents the effect of the magnetic flux upon the bismuth resistors, and is more clearly shown in later oscillograms, while the other alternating component is merely due to an induced voltage in the coils of the bridge. This indicates that the bridge is not entirely noninductive.

The first problem was to design the bridge element so that it would be as nearly as possible noninductive. Some means must then be provided to balance out of the fluxmeter branch circuit any a-c voltage still induced. Finally the use of the bridge in a-c and transient magnetic fields must be studied to determine whether or not it does give consistent results in a-c fields, and, as far as the apparatus available will allow, determine its limits with respect to frequency.

Changes in Construction of the Instrument

To reduce the self-inductance of the bridge element, the wire for the various resistors was enameled and was wound in noninductive spirals, with the turns as closely together as possible. This winding also resulted in a smaller coil, for the same resistance, than was obtained in the instrument previously described. To eliminate any possible voltage generation between the bridge terminal and the resistor coils, all leads were made of copper foil of similar shape and size, and were

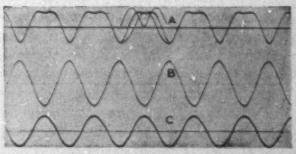

Figure 2. Oscillogram showing the distorted fluxmeter current before the bridge is provided with an a-c compensating coil

A—Current in fluxmeter
B—Induced voltage from exploring coil in air gap of magnet
C—Voltage across the exciting coils of magnet

stacked one upon the other, each insulated from the next by a thin film of paper. The details of this construction are clearly shown in figure 3.

A number of other improvements were made in the bridge element. Either lead or tin wire was found very satisfactory for use as balancing resistors, since they are nonmagnetic and have temperature coefficient of resistance about equal to or slightly higher than the coefficient for bismuth. By use of either, a slight negative reading previously experienced under certain conditions was entirely eliminated, as will be more fully discussed later. To stiffen the end of the bridge and more adequately to protect the resistor coils, the leads were tapered to a point near the coil end, in order that pieces cut from thin celluloid and shaped to extend around the outer edges of the coils might be

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1. For all numbered references, see list at end of paper.

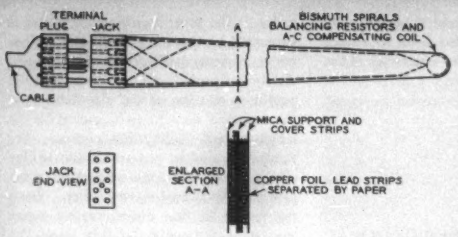

Figure 3. Bridge and terminal block assembly

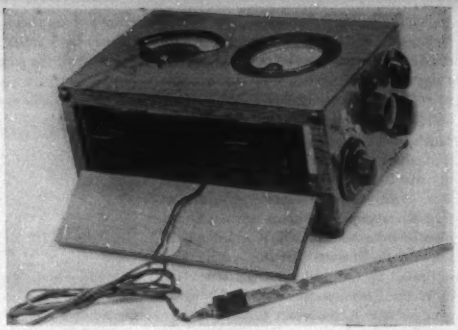

Figure 4. View of completed meter

cemented very securely to the mica support. The terminal block was divided into two parts, with the flexible leads to the instrument securely soldered into plugs in the one part, and corresponding jacks soldered to the copper-foil leads in the other. This method allows the bridge to be easily detached for checking or repairs, but is of most value in making adjustments during construction. By this means also two or more bridges may be used with the same meter. For example, the element of one bridge may be very small in diameter for measuring fields of very small area, while another may be designed with a much larger area, but sensitive to much lower field densities.

To balance out any a-c voltage still generated in the bridge coils, an a-c compensating coil of two or three turns of copper wire was wound around the outside of one set of the bridge coils. The terminals of this coil were carried to the meter and connected across a resistance, an adjustable portion of which is in series with the fluxmeter, as is shown in figure 1. By means of an oscillograph this adjustment may be set to give zero a-c current in the fluxmeter branch when the bridge is in a strong a-c magnetic field and the meter battery circuit is open. No difficulty was experienced in making this setting, and once it was made no further alteration was needed. When the instrument is used for direct current this coil has no function and is virtually outside the working circuit.

The controlling and indicating portion of the instrument was not greatly changed. For use with the oscillograph, two extra terminals were added, and a single-pole double-throw switch was provided to throw either the milliammeter or the oscillograph terminals into the flux-measuring position. The completed instrument, ready for use, is shown in figure 4.

The experimental tests may be divided into three groups: calibrations, phase relations, and examples of transient oscillograms.

Calibration Tests

For use in most of the tests, an electromagnet with a core of laminated transformer steel was designed and constructed. The pole faces of the square core were tapered and turned to a diameter of about four centimeters, and were spaced with an air gap of about 0.5 centimeters. With this magnet an a-c flux density of from eight to ten kilogausses could be obtained, though at the higher values the core would become noticeably warm.

The average value of the a-c magnetic-flux density was calculated from the area, the number of turns, and voltage induced in an exploring coil placed in the air gap. Three different exploring coils were used, each with a diameter of about 3.2 centimeters, and with 2, 30, and 100 turns, respectively, of number 38 enameled copper wire. The induced voltage was measured by means of a 15-volt rectifying type of voltmeter, with a resistance of 2,000 ohms per volt. The frequency was held at the proper value by using an oscilloscope to compare it with the power company's 60-cycle current upon which the electric clocks depend.

A check on the results obtained by the rectifying voltmeter was made by means of a high-grade thermocouple voltmeter. In this case the induced voltage was obtained by adding the computed drop in the coil to the voltmeter reading. The two methods checked very closely. For the major portion of the calibration work a good sine-wave voltage source was used as far as possible. Later distorted wave shapes were also used to check the calibration on non-sine waves.

The calibration curves for a constant temperature of 22 degrees centigrade, and for three different values of current supplied to the bridge circuit are shown in figure 5. All calibration curves made by means of direct current are shown in full lines; those for alternating current are shown in dashed lines. In all the a-c calibrations the average value of flux was used. Since the rectifying type of voltmeter indications are proportional to the average values, its reading will

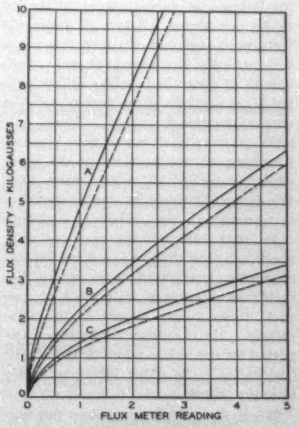

Figure 5. Calibration curves for magnetic fluxmeter

All curves taken at 22 degrees centigrade
Full lines indicate d-c calibrations
Dashed lines indicate a-c calibrations
Average values of a-c flux used throughout
A—Calibrations using three milliamperes in bridge
B—Calibrations using ten milliamperes in bridge
C—Calibrations using 25 milliamperes in bridge

indicate average values regardless of the voltage wave shape. In making checks with the thermocouple type of meter, care was used to select a good sine wave of voltage as the source.

The change in the resistance of bismuth when placed in a magnetic field varies somewhat with the temperature at which the bismuth is maintained. The change becomes less per unit of flux density as the temperature is increased. In the previous paper where only d-c fields were used this change was indicated by calibration curves at several different temperatures. The same changes take place when used for alternating current though the actual calibration curves at other temperatures are not shown. While this change is not quite linear with respect to temperature, over the usual range, the actual flux densities are roughly one per cent per degree lower for lower temperatures, or higher for higher temperatures, than the values shown for 22 degrees centigrade. Where more accuracy is desired, the values must be interpolated from a set of calibration curves covering the temperature involved, or by means of an empirical formula derived from such curves or data.

The a-c calibrations were carried out for frequencies varying from 12 to 540 cycles per second. Below 12 cycles the instrument pointers vibrated too much for reading. No apparatus was available to go above 540 cycles; in fact only the lower portions of the curves could be checked for this frequency. Where possible, portions of all curves were checked by means of two or more of the three exploring coils. All values taken over this range of frequencies, and in checking by means of the different exploring coils, were seldom over two per cent above or below the average value shown. Since the guaranteed accuracy of the rectifying voltmeter is only four per cent, these values appear quite satisfactory. No tendency whatever appeared for the values taken at the higher frequencies to be either higher or lower than the others.

Seemingly the direct current and the average values for the alternating current should fall on the same curve, but the experimental data proved this to be not so. Were this caused by the lag of the resistance change as found by Konig[2,3] more flux would probably be necessary to give the same meter reading rather than less, and the effect should increase as the frequency increased. Nor could it be accounted for by eddy-current losses, inductance, or capacity in the circuit since these would vary with frequency and would also tend to reduce rather than increase the sensitivity of the meter. The most logical explanation is suggested by the wave shape of the fluxmeter current oscillograms shown most clearly in figures 7 and 9. Because of the nonlinear relation of the flux density to the resistance change, as is evident by the direct-current calibration curves, the resulting variable current in the bridge circuit is decidedly non-sine wave when produced by a sine wave of flux. Since the torque in the direct-current meter used as a fluxmeter depends upon the average of this cyclic current, this average, due to the flat-topped waves, would be somewhat higher than for sine waves of similar amplitude and thus the reading for the average value of the alternating-current flux would be greater than would be obtained were the meter current waves sinusoidal.

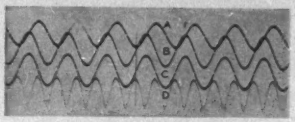

Figure 6. Phase relations at 60 cycles per second

A—Current in the coil of magnet
B—Voltage across coil of magnet
C—Induced voltage from exploring coil in air gap
D—Magnetic flux in air gap by means of fluxmeter

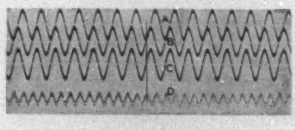

Figure 7. Phase relations at 280 cycles per second

A—Current in coil of magnet
B—Voltage across coil of magnet
C—Induced voltage from exploring coil in air gap
D—Magnetic flux in air gap by means of fluxmeter

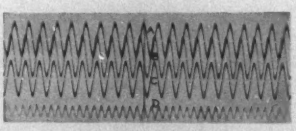

Figure 8. Phase relations at 480 cycles per second

A—Current in coil of magnet
B—Voltage across coil of magnet
C—Induced voltage from exploring coil in air gap
D—Magnetic flux in air gap by means of fluxmeter

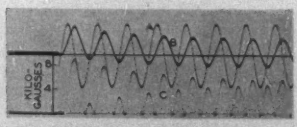

Figure 9. Starting transient when a-c voltage is switched across coil of magnet

A—Induced voltage from exploring coil in air gap
B—Current in coil of magnet
C—Magnetic flux in air gap by means of fluxmeter

The accuracy with which readings could be duplicated or checked between different meters, using reasonable care in determining the temperature, was seldom over two per cent in error when used for direct current. Only the one meter for use in alternating current has so far been constructed and calibrated; thus it would be difficult to state what accuracy could be expected, since the apparatus used for calibration could not be depended upon for an accuracy of more than four per cent, and this was the only possible means of obtaining a comparison.

No difference could be detected in the readings when the wave shape was distorted as compared to sine waves. Also since the highest frequency used is a rather high order of harmonics for the lowest and the calibration for all frequencies used fell on the same calibration curve, it seems evident that within the range of frequencies covered the accuracy of the meter is not noticeably affected by the wave shape of the flux.

Phase Relations

The second problem was to study the time-phase relations of the bismuth resistance and magnetic flux as they were varying. Investigations made in this field by Konig, Heurlinger, and others,[2–6] indicate a lag of the bismuth resistance change. Konig, who probably made the most extensive investigation, used a make-and-break device to produce changes in the magnetic field. This would probably be equivalent to using a rather high alternating frequency. The problem attempted in the present research was limited to what might be termed commercial frequencies and their harmonics.

For such study a series of some twenty or more oscillograms were taken over a range of from 60 to 480 cycles per second. Representative oscillograms for 60, 280, and 480 cycles per second are shown in figures 6, 7, and 8.

No lag in the resistance change can be detected at 60 cycles, but at 280 cycles a lag appears of about 14 electrical degrees, and at 480 cycles this has further increased to about 24 electrical degrees. However, these measured lags must not be considered more than approximate, since the oscillograph light and vibrator adjustments can often cause slight apparent phase shifts when none are present. For example, in figure 6, the magnetic-flux record appears slightly to lead the voltage values. The conclusions stated are based upon the average results of the large number of oscillograms taken. Unusual care was exercised in taking sets with the minimum of changes in adjustments, while other sets were purposely taken after adjustments had been changed.

Magnetic Transients

The third problem was to obtain some transient oscillograms of the magnetic field, together with the corresponding current and voltage values. The oscillogram in figure 9 shows the switching of a 60-cycle voltage across the coil of the magnet previously described. The unusual height of the transient-flux values gives an indication of the instantaneous mechanical forces acting during the transient period. The usual transient and steady conditions when a single-phase alternator is short circuited are shown in figure 10. The variations in the field current *C* after short circuit give some indication of the armature reaction on the field flux but the actual flux variations in *D* show exactly how the air-gap flux is varying as well as its phase relations to the field and armature current changes. The variations of the air-gap flux due to the armature slots and teeth are also very evident. Figure 11 shows the flux distribution under the pole face of a stationary direct-current motor, when the shunt field is excited. This was taken by moving the bridge element along the air gap. The oscillograph drum was rotated by a thread extending from its pulley to the bridge. Since the bridge was moved with the hand the oscillogram shows some unevenness which should not be present. Many other interesting and valuable studies could be made on stationary and running machines, as well as on other equipment.

Directional Variations

An observation may be made here, not strictly in line with the subject at hand but nevertheless relating to an interesting and important feature of the instrument.

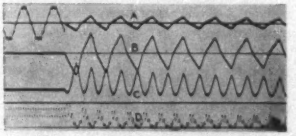

Figure 10. Transient from no load to almost short circuit in a single-phase alternator

A—Alternator terminal voltage
B—Alternator armature current
C—Alternator d-c field current
D—Air-gap flux under pole

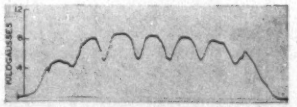

Figure 11. Distribution of magnetic flux under the excited pole of a stationary d-c motor

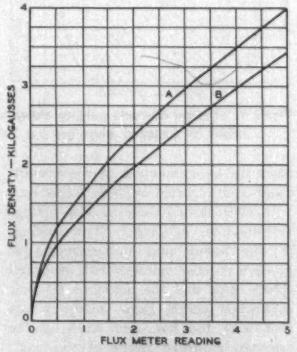

Figure 12. Directional effect in use of magnetic fluxmeter

Curves taken using 25 milliamperes in bridge
A—Magnetic flux parallel to plane of coils in bridge
B—Magnetic flux perpendicular to plane of coils in bridge

In the discussion on the previous paper[4] a set of curves was shown in which the bridge element was held with the plane of its coils parallel to the magnetic-flux lines. At very low-flux densities the readings were negative; at slightly higher values the negative reading decreased, finally changed to positive, and continued to increase. A greater density was always required to give the same reading than when the plane of the bridge coils was held perpendicular to the lines of flux.

By using lead or tin wire instead of nickel for the balancing resistors, no negative readings are obtained; the calibration curves obtained with the plane of the coil held parallel with the lines of flux, and also held perpendicular to the flux, are shown in figure 12. The directional effects of the magnetic field upon bismuth as well as upon other materials has been quite fully investigated in previous researches.[7]

At first thought this change might appear disadvantageous, but it has the one important advantage of indicating the resultant direction of the flux as perpendicular to the plane of the coils when the reading is maximum, or as being parallel to the plane of the coils when the reading is minimum. In the measurement and plotting of the distribution of the flux in irregular fields this indication would prove of considerable value.

Conclusions

While this research by no means exhausts the field for study, it has definitely proved that the instrument is of value in the measurement of alternating current and transient as well as direct-current magnetic fields. Within the range studied, the frequency has no effect upon the calibration. The tendency of the bismuth resistance to lag behind the flux changes found by previous investigators has been verified, though this lag at the usual commercial power frequencies either cannot be detected or is of very low magnitude. The instrument is thus well adapted to many studies in the alternating current and transient fields.

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Polarity Limits of the Sphere Gap

By F. O. McMILLAN
FELLOW AIEE

Synopsis: It is found that 60-cycle polarity characteristics correlate with the positive and negative impulse calibration curves for grounded sphere gaps sufficiently well to use them for determining the polarity limits for sphere gaps. The available data show that the maximum spacing at which a grounded sphere gap has equal positive and negative spark-over is a linear function of the size of the spheres. From this relation, it follows that the maximum sparking distance for equal positive and negative spark-over, expressed as a per cent of the diameter of the spheres, is not constant for all sphere diameters. Therefore, arbitrary polarity limits expressed in terms of the diameter of the sphere cannot apply to all sizes of sphere gaps.

EXTENSIVE use of sphere gaps in high-voltage testing and research makes it imperative to have complete data on their characteristics and limitations, particularly when the gaps are used for measuring impulse voltages. This paper describes a method of using the 60-cycle polarity characteristics for sphere gaps to determine their polarity limits of spark-over in measuring impulse voltages. Empirical expressions are derived for the equal positive and negative spark-over limit of the sphere gap in centimeters and also as a function of the diameter of the spheres. The large amount of data obtained from 60-cycle polarity characteristics and impulse tests made in the local laboratory over a period of eight years and by other investigators, have been carefully correlated in arriving at these empirical equations. As more data become available for large spheres at the higher voltages, similar expressions can be derived for the interesting but erratic transition region which is not used for high-voltage measurements. The laws proposed are applicable to the measurement of impulse voltages for which the time from zero to flashover voltage is one microsecond or more. This impulse time is the same as that for which the recommended AIEE sphere-gap calibration standards apply.

The sphere gap has been an accepted device for measuring high voltages since 1913;[1,2] however, the polarity characteristics of the grounded sphere gap were not observed until 1929. In October 1929, Lusignan[3] reported that 60-cycle symmetrical voltage only sparked over a 50-centimeter grounded sphere gap when the ungrounded sphere was negative if the spheres were one sphere diameter apart. He also reported that

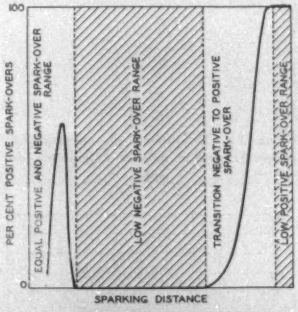

Figure 1. Typical 60-cycle polarity characteristic for grounded sphere gap

when the separation was 69 centimeters, spark-over occurred on both polarities.

In 1929, during some impulse voltage investigations at Oregon State College, it was found that measurements of positive impulse voltages with grounded sphere gaps and the standard 60-cycle calibration curves gave voltage values that were too low over much of the accepted standard range of the gap.[4] This observation led to a study of the polarity characteristics of sphere gaps at 60 cycles to determine the extent and nature of the polarity effects at power frequencies. Complete 60-cycle polarity characteristics were obtained for several different types of gaps including sphere gaps. The latter showed four distinct polarity ranges occurring at different spacings of the spheres.[4]

The observed polarity characteristics of grounded sphere gaps when measuring impulse voltages were confirmed by a number of investigators, notably Allibone, Hawley, and Perry[5] in June 1933, Meador[6] in June 1934, and Bellaschi and McAuley[7] in June 1934.

General recognition of the difference in the positive and negative spark-over of grounded sphere gaps has led to extensive revision of sphere-gap calibration standards in the United States and abroad. Notable progress has been made by the AIEE subcommittee on sphere-gap calibrations in assembling positive, negative, and 60-cycle calibration data for the standard sizes of sphere gaps. Supplementing these data, it is important to know accurately the polarity limits of these gaps over a wide range of spacings. This information is readily obtained from the 60-cycle polarity characteristics, because sphere-gap polarity effects are essentially independent of the duration of the voltage wave for waves of one to two microseconds duration and longer.[8,9]

60-Cycle Polarity Characteristics

A typical 60-cycle polarity characteristic for a grounded sphere gap is shown in figure 1. Two methods of determining these characteristics, one utilizing visual Lichtenberg figures and the other a neon cathode-glow lamp, have been described in papers[4,6] previ-

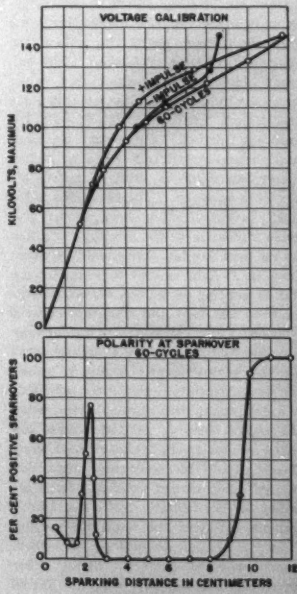

Figure 2. Characteristics of 6.25-centimeter grounded sphere gap

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1. For all numbered references, see list at end of paper.

ously cited. The 60-cycle polarity characteristics shown in figures 1, 2, and 3 cover a much wider range of sparking distances than are useful in measuring voltages; however, they serve to give a complete picture of the four distinct polarity ranges characteristic of grounded sphere gaps.

Both positive and negative spark-over occurs in the first range showing that the positive and negative spark-over voltages are essentially equal. The upper limit of this range is of great importance, because it shows the maximum sparking distance over which the sphere gap can be used without objectionable polarity effect.

Positive spark-over does not occur in the second range, showing that the negative spark-over voltage is less than the positive. This region is important, because it includes the remainder of the range of the sphere gap that is useful for measuring voltages and shows the spacings over which positive and negative calibrations must be used.

In the third range, both positive and negative spark-over occurs, and the gap is very erratic in its behavior, because corona forms on the ungrounded sphere at voltages that are lower than the spark-over value. This range covers the transition from 100 per cent negative spark-over to 100 per cent positive spark-over.

One hundred per cent positive spark-over occurs in the fourth range due to the formation of heavy corona streamers preceding spark-over. These corona streamers give the gap characteristics similar to those of a point-to-plane gap.

Sphere-gap spacings falling in ranges three and four are almost entirely of theoretical interest, because they have very little practical value for voltage measurements.

Correlation of 60-Cycle Polarity Characteristics With Impulse Calibrations

When the positive and negative impulse voltage calibration curves for a sphere gap are plotted directly above the 60-cycle polarity characteristic, using a common scale of abscissas, the correlation of the 60-cycle characteristic with the calibration curves is clearly shown. This has been done for the 6.25-centimeter and 50-centimeter sphere gaps in figures 2 and 3. These sphere gaps were selected on account of the large difference in size and because complete characteristics were available. Both the 60-cycle and impulse data for the 50-centimeter gap were taken by Meador[6] in another laboratory. The wave used for the 6.25-centimeter sphere-gap impulse voltage calibration was a 1x5 microsecond wave, while the 50-centimeter gap was calibrated with a 1.5x40-microsecond wave.

Table I. Polarity Limits of Spark-Over for Grounded Sphere Gaps

Diameter of Spheres (Centimeters)	Sphere-Gap Spacing in Centimeters and Per Cent Sphere Diameter											
	Equal Positive and Negative Spark-Over Range			Low Negative Spark-Over Range			Transition Negative to Positive Spark-Over			Low Positive Spark-Over Range		
	Minimum	Maximum		Minimum	Maximum		Minimum	Maximum		Minimum	Maximum	
	Centimeters	Centimeters	Per Cent Sphere Diameter	Centimeters	Centimeters	Per Cent Sphere Diameter	Centimeters	Centimeters	Per Cent Sphere Diameter	Centimeters	Centimeters	Per Cent Sphere Diameter
2.00	*											
2.54	0	2.2	87	2.2	3.3	130	3.3	3.8	150	3.8	∞	∞
6.25	0	3.	48	3.	8.	128	8.	11.	176	11.	∞	∞
12.5	0	5.	40	5.	15.	120	15.	*				
25.	0	9.	36	9.	30.	120	30.	*				
50.	0	13.	26	13.	50.	100	50.	70.	140	70.	∞	∞
75.	0	22.	29	22.	*							
100.	0	30.	30	30.	*							
150.	*											
200.	0	55.	28	55.	*							

* Limits of available data.

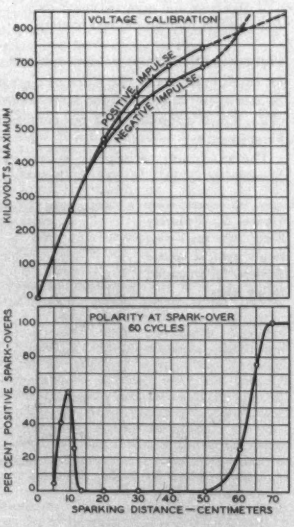

Figure 3. Characteristics of 50-centimeter grounded sphere gap

The upper limits of the equal positive and negative spark-over ranges for the two polarity characteristics coincide quite well with the points of divergence for the positive and negative impulse calibration curves. The limit for the 6.25-centimeter sphere gap is slightly higher than the branching point for its impulse calibration curves, and the limit for the 50-centimeter sphere gap is essentially coincident with the point of divergence of the calibration curves.

The range of zero positive spark-over is wider than the usual range of impulse calibration curves, and it clearly shows the gap limits over which positive and negative calibration curves must be used for impulse measurements.

The polarity characteristics shown were taken on gaps with the ungrounded sphere mounted directly above the grounded sphere and with the sparking surface of the grounded sphere four sphere diameters above the ground plane. This is the usual position of sphere gaps when making high-voltage measurements. Other 60-cycle polarity characteristics taken with the sphere gap mounted in a horizontal position with respect to the ground plane were essentially the same as those for the vertical gap except the second range over which there are no positive spark-overs was shortened, because the transition from negative to positive spark-over occurred at a shorter gap spacing.

Polarity Limits From 60-Cycle Polarity Characteristics

Close correlation between impulse voltage calibration curves and the 60-cycle polarity characteristics makes it possible to take from the latter characteristic curves the sparking distances defining each of the four distinct polarity ranges for the different sizes of sphere gaps. The polarity characteristics at 60 cycles are readily determined if an adequate source of high voltage is avail-

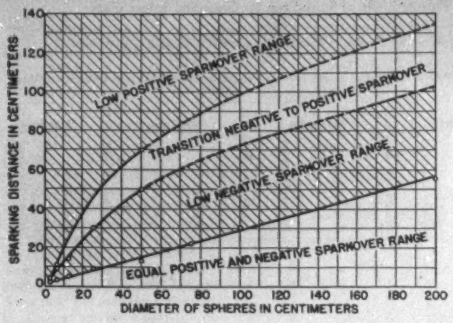
SPARKING DISTANCE IN CENTIMETERS
DIAMETER OF SPHERES IN CENTIMETERS
LOW POSITIVE SPARKOVER RANGE
TRANSITION NEGATIVE TO POSITIVE SPARKOVER
LOW NEGATIVE SPARKOVER RANGE
EQUAL POSITIVE AND NEGATIVE SPARKOVER RANGE

Figure 4. Polarity limits of spark-over in centimeters for grounded sphere gaps

able. The maximum voltage available for this investigation was limited, and hence it was necessary to draw upon data published by Meador[4] in 1934 to show the polarity limits for the large standard sphere gaps. Meador's results, which are the only data published since the original paper[4] in 1930, are the most extensive available, but they are not complete for the large sphere gaps at wide spacings.

The polarity limits of spark-over for grounded sphere gaps are shown in table I. These data are sufficient to determine the upper limit of the very important equal positive and negative spark-over range for all standard sphere gap sizes except the 2-centimeter spheres, but they are quite inadequate for the other three higher polarity ranges. It is hoped that investigators with high-voltage facilities available will extend and check the existing data.

The data in table I are shown graphically in figures 4 and 5. Figure 4 shows that the sparking distance in centimeters, marking the upper limit of the equal positive and negative spark-over range, is a linear function of the diameter of the sphere. The equation of the curve is:

$$S = 0.267\,D + 1.50 \qquad (1)$$

where

S = maximum sparking distances, in centimeters, for equal positive and negative spark-over.

D = sphere diameter in centimeters.

This is a very interesting and important relationship, and, if confirmed by more complete and extensive data, it shows that the more or less generally accepted idea that small sphere gaps are useful for measuring impulse voltages over a smaller per cent of sphere diameter separation than large gaps is erroneous. These data show that just the opposite is true. If the sparking distance S in equation 1 is expressed as a per cent of sphere diameter D, the following equation may be written:

$$S_D = 26.7 + \frac{150}{D} \qquad (2)$$

where

S_D = maximum sparking distance, in per cent of sphere diameter, for equal positive and negative spark-over.

D = sphere diameter in centimeters.

From equation 2 it is apparent that for small values of D the value of S_D will be relatively large, and for large values of D, it will approach 26.7 per cent as a lower limit.

The maximum permissible sphere-gap spacing to obtain equal positive and negative spark-over voltage within the useful range of the gap are given in table II. These are calculated values from equations 1 and 2 which give the maximum spacings in centimeters and in per cent of sphere diameter. A comparison of the calculated values in table II with the experimental values in table I shows that the agreement is well within the limits of experimental accuracy.

Reference to the experimental values in table I shows that the 2.54-centimeter sphere gap shows no appreciable polarity effect until a spacing of 87 per cent of sphere diameter is reached, while the 200-centimeter gap shows a polarity effect at 28 per cent of diameter separation. The maximum sparking distances for equal positive and negative spark-over, expressed in per cent of sphere diameter, are shown graphically in figure 5.

In the light of these data, it is not advisable to establish arbitrary sphere-gap limits expressed in terms of sphere diameter and apply them to all gaps regardless of size, as has been the practice in previous standards for measuring high voltage.

The boundary curves for the low negative spark-over range and the transition from low negative to low positive spark-over are only reasonably well established up to 50-centimeter diameter spheres; beyond that point the curves are located entirely by extrapolation without adequate data, and the curves may be very much in error. These portions of the sphere-gap characteristics are beyond the limits that are useful for measuring voltage, but it is believed when data are available to establish them accurately, they will assist in obtaining a better understanding of sphere-gap characteristics within the useful range. The available data show that as sphere gaps increase in size, the polarity limits do not increase to the proportions that would be expected. This may be due, at least in part, to abnormal flux distortion because of inadequate free space around the large gaps.

When important measurements are to be made, a low-frequency polarity characteristic may be taken on the sphere gap in position to determine whether or not the polarity characteristics are normal. This precaution is important with large gaps, because it is a well-known fact

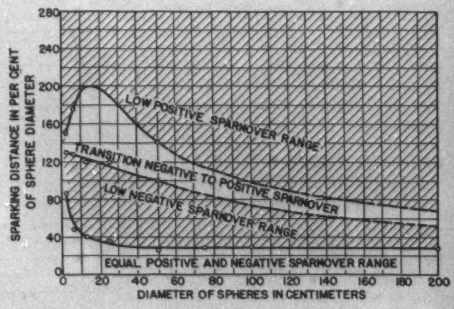
SPARKING DISTANCE IN PER CENT OF SPHERE DIAMETER
DIAMETER OF SPHERES IN CENTIMETERS
LOW POSITIVE SPARKOVER RANGE
TRANSITION NEGATIVE TO POSITIVE SPARKOVER
LOW NEGATIVE SPARKOVER RANGE
EQUAL POSITIVE AND NEGATIVE SPARKOVER RANGE

Figure 5. Polarity limits of spark-over in per cent of sphere diameter for grounded sphere gaps

Table II. Maximum Sparking Distance for Equal Positive and Negative Spark-Over Voltage for Grounded Sphere Gaps

Values Calculated From Empirical Equations

Diameter of Spheres Centimeters	Maximum Sparking Distance Centimeters $S = 0.267D + 1.50$	Maximum Sparking Distance Per Cent Sphere Diameter $S_D = 26.7 + \frac{150}{D}$
2.00	2.03	101.7
2.54	2.18	85.7
6.25	3.17	50.7
12.5	4.84	38.7
25.	8.18	32.7
50.	14.9	29.7
75.	21.5	28.7
100.	28.2	28.2
150.	41.5	27.7
200.	54.9	27.5

that the flux distortion due to the ground plane causes the polarity effect, and when this distortion is abnormal, standard calibration data no longer apply.

Concluding Summary

1. The 60-cycle polarity characteristics for grounded sphere gaps show four distinct polarity ranges:

I. Equal positive and negative spark-over.

II. Low negative spark-over.

III. Transition from low negative to low positive spark-over.

IV. Low positive spark-over.

2. The correlation of the 60-cycle polarity characteristics with the positive and negative impulse voltage calibration curves for grounded sphere gaps is such that the 60-cycle polarity characteristics may be used to determine the impulse polarity limits for measuring voltage waves that increase from zero to flashover in one microsecond or more.

3. All available data show that the maximum sparking distance for equal positive and negative spark-over is a linear function of sphere diameter over the entire range of standard sphere-gap sizes. The equation for the relationship is:

$$S = 0.267\,D + 1.50$$

4. Small grounded sphere gaps may be used over a greater per cent of diameter separation than large gaps without appreciable polarity effect.

5. The maximum sparking distance for equal positive and negative spark-over voltage for grounded sphere gaps, expressed as a per cent of the diameter of the spheres, is a variable function of the sphere diameter. The equation for the relationship is:

$$S_D = 26.7 + \frac{150}{D}$$

Therefore, it is inadvisable to establish arbitrary sphere-gap polarity limits expressed in terms of sphere diameter and apply them to all gaps regardless of size.

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Discussion

J. R. Meador (General Electric Company, Pittsfield, Mass.): This is an interesting continuation of the work reported by the author and E. C. Starr in 1931.

I wish to comment on the statement:

The available data show that as sphere gaps increase in size, the polarity limits do not increase to the proportions that would be expected. This may be due, at least in part, to abnormal flux distortion because of inadequate free space around the large gaps.

The implications of this statement are important to those who expect to use sphere gaps over a wide range of gap spacings.

In the tests reported in the writer's paper ("Calibration of the Sphere Gap," J. R. Meador, AIEE Transactions, volume 53, 1934, pages 942–8) it was found that the transition points from partial negative spark-over to all negative spark-overs (usually near one-fourth diameter spacing) and from all negative spark-overs to partial negative spark-overs (usually near diameter spacing) were not entirely consistent. This was particularly true of the 6¼-centimeter sphere gap which had no all-negative spark-over range.

In the early part of 1934 the writer made a few tests on several sizes of spheres to determine the effect of surroundings on the spark-over voltage and polarity characteristics. Some of the results obtained may be of interest.

With 6¼-centimeter spheres at 6¼-centimeter spacing and the sparking point of the grounded sphere 4.1 diameters above a flat grounded plate, 100 per cent negative spark-overs were obtained. When the spacing above ground was increased to 5.7 diameters, only 80 per cent of the spark-overs were on the negative half cycle. With four vertical line-potential wires spaced ten inches from the center line of the spheres, the voltage was approximately the same as without shielding wire but all spark-overs were positive polarity. In this case the spheres were overshielded.

Similar effects of shielding were obtained with the 12.5-centimeter and 50-centimeter spheres. In each case when the shielding wires were adjusted to give equal positive and negative spark-overs, the 60-cycle calibration curve was in close agreement with the calculated curve for isolated sphere gaps. Similarly, the positive and negative polarity impulse spark-over curves were practically the same.

These comments are made to emphasize the fact that care must be exercised when the spheres are used at spacings above ¼ to ½ of diameter for either low frequency or impulse measurements, since the surroundings may appreciably influence the polarity characteristics and consequently the spark-over voltage on both polarities.

Abe Tilles (University of California, Berkeley): Professor McMillan's most interesting paper presents, logically assembled, a great deal of useful information. It answers numerous questions and raises still other questions.

In the so-called "equal positive and negative sparking range" of figures 1, 2, and 3 would it not be more correct to alter the nomenclature somewhat? Possibly "range of spark-over of both polarities" would do. The curve seems to have a definite structure in that range and there seem to be strictly "equal" spark-overs only where the curve is, within the limits of error, at an ordinate of 50 per cent. How well defined is the curve in that region? How many individual spark-overs is it necessary to observe to establish a point on this curve?

In comparing the 60-cycle polarity curves of figure 3 for 50-centimeter spheres and of figure 2 for 6.25-centimeter spheres an upturn is observed at the smallest spacings of figure 2. Presumably, for such a curve on the still smaller 2.5-centimeter spheres, and for measurements at still smaller spacings, this upturn might be observable in greater detail. It would be of interest if Professor McMillan could publish such a curve for the smallest spheres and spacings at which he obtained data. Small gaps may show interesting differences in behavior from large gaps.

It is clear, I believe, that any appreciable even harmonic distortion in the voltage wave shape would introduce error into the results. In what way, and to what degree of refinement, was the voltage wave shape controlled or observed?

In assembling these data Professor McMillan has doubtless had occasion to consider what varying mechanisms of spark-over account for the different "polarity ranges" at different spacings. It would be helpful if he would care to state more fully what he considers these mechanisms of spark-over to be.

D. W. VerPlanck (Yale University, New Haven, Conn.): As pointed out by Professor McMillan the negative impulse spark-over voltage for grounded sphere gaps is lower than the positive at intermediate spacings but becomes higher at large spacings. From this, one might expect that with alternating voltage in the intermediate range of spacings, all

spark-overs would have negative polarity, and that at the spacing where the impulse characteristics cross, the polarity of the alternating voltage sparks would change abruptly from negative to positive. Actually, however, as shown in the paper, the transition from negative to positive polarity is a gradual one extending over a range which includes the spacing at which the impulse characteristics cross (see figures 2 and 3). That the transition is not abrupt may possibly be because of an insufficient continuous supply of initiating electrons in critical parts of the gap. In this connection it would be interesting to know whether or not McMillan's data were obtained from tests on irradiated gaps.

While the middle of the transition range may be at the spacing where the impulse characteristics cross, the transition appears to begin, as will be shown below, at the spacing for which the ratio of positive to negative impulse voltage is a maximum.

The ratio of positive to negative impulse spark-over voltage as a function of spacing to diameter ratio for the various standard sphere sizes is plotted in the figure accompanying this discussion. These curves, obtained with the aid of empirical formulas presented in a recent paper ("A New Correlation of Sphere-Gap Data," D. W. VerPlanck, AIEE TRANSACTIONS, January 1938, page 45) are in accord with the revision of the AIEE proposed sphere-gap standards dated December 1937. The dashed portions of the curves are extrapolations by means of the formulas beyond the region actually covered by the standards. The maxima of these curves occur at spacing to diameter ratios shown in table I of this discussion, which increase with decreasing sphere diameter. An examination of Professor McMillan's figure 5 shows that the lower boundary of his transition region occurs at spacing to diameter ratios, also shown in table I, which are substantially the same as those for the maximum ratio of positive to negative impulse voltage. Thus independent evidence is presented confirming Professor McMillan's results at least to the extent of showing that there must be some change in the mechanism of sparking commencing at about the spacing to diameter ratios shown in table I.

Another, though less definite check is that each of the curves showing the ratio

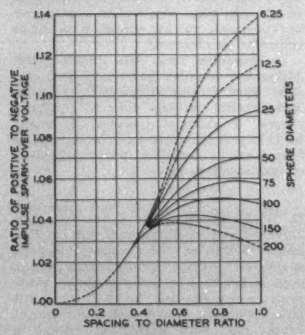

Figure 1

Table I

Sphere Diameter (Centimeters)	Spacing to Diameter Ratio: For Maximum Ratio of Positive to Negative Impulse Spark-over Voltage	Spacing to Diameter Ratio: For Beginning of Transition Negative to Positive Spark-over Polarity
200	0.55	0.55
150	0.65	0.60
100	0.80	0.75
75	0.87	0.85
50	1.0	1.0
25	Greater than 1.0	1.15

of positive to negative impulse spark-over voltage has a point of inflection at roughly the same spacing to diameter ratio as the lower boundary of the "low negative spark-over range" in Professor McMillan's figure 5. This may indicate another change in the character of the spark discharge.

F. O. McMillan: It is suggested by Professor VerPlanck that the rather gradual transition from negative to positive spark-over may be due to an insufficient continuous supply of initiating electrons in critical parts of the gap, and he asks whether the data were obtained from irradiated gaps. The gaps were not irradiated to obtain any of the data used, hence the initiating electrons were supplied entirely by the normal ionization of the air in the interelectrode space. Some experimental evidence at hand indicates that the number of ions present does influence the polarity characteristics near the transition regions. However, it is believed that the rather long transition range between negative and positive spark-over is largely due to the fact that it occurs over the range of gap spacings where the corona discharge and spark-over curves are diverging. When corona occurs at a slightly lower voltage than complete spark-over, voltage disturbances are set up by the corona that cause spark-over to occur on both polarities. As the gap spacing is further increased and the voltage difference between corona formation and spark-over becomes greater, the corona streamers on the ungrounded sphere reach sufficient length to cause the gap to behave somewhat like a point-to-plane gap, and the spark-over always occurs when the ungrounded sphere is positive.

The graphs of the ratio of positive to negative impulse spark-over voltage as a function of spacing to diameter ratio obtained by Professor VerPlanck from his recently developed formulas for sphere-gap characteristics lead to conclusions that agree remarkably well with the data in the paper. This independent evidence aids materially in establishing the dependability of the results.

A question of nomenclature is raised by Doctor Tilles. He suggests "range of spark-over of both polarities" in place of "equal positive and negative spark-over range." Whether or not this is desirable depends upon the quantities to which "equal" is applied. If an equal number of positive and negative spark-overs is understood, the point is well taken; however, the expression is used in the paper to state that the magnitudes of the positive and negative spark-over voltages are essentially equal for the range in question. This use is believed to be justified because if both positive and negative spark-overs occur at a given spacing, even though they are unequal in number, the magnitudes of the positive and negative spark-over voltages must be essentially equal within the limits of measurement, otherwise spark-over would occur only on one polarity.

The ordinates of the polarity characteristic curves for the range of gap spacings in question are determined by the laws of probability and are established by taking a relatively large number of observations at each point. Usually 25 to 50 observations will locate a point reasonably well, but in most instances a hundred or more observations were made to determine each point on the polarity characteristics.

The 60-cycle polarity characteristics for different sizes of grounded sphere gaps all show four distinct polarity ranges as described in the paper, but the relative widths of the ranges vary with the size of the spheres as shown by the curves in figure 5. The upward inflection of the 6.25-centimeter sphere-gap polarity characteristic at close spacings is characteristic of small gaps and is exhibited to an even greater degree by the 2.54-centimeter sphere gap. The polarity characteristic curve for a 2.54-centimeter sphere gap is shown in figure 9 of the paper "The Influence of Polarity on High-Voltage Discharges," AIEE TRANSACTIONS, volume 50, page 25.

As Doctor Tilles points out, even harmonic distortion of the 60-cycle voltage wave shape would introduce errors in the results. This was guarded against by using an alternator with a good wave form, by using field control on the alternator to vary the voltage, and by the careful elimination of all voltage-distorting phenomena such as nonlinear circuit elements and corona discharges.

A gap that is physically and electrically symmetrical does not show any polarity effect. The mechanism of spark-over for each of the four polarity ranges of the grounded sphere gap can, therefore, be accounted for reasonably well by the dielectric flux distortion due to the ground plane and its resulting influence on the ionization phenomena in the gap.

Consider a grounded sphere gap mounted perpendicular to the ground plane with the spark gap four to five sphere diameters above it, and the lower sphere connected electrically to the plane. When voltage is applied to such a gap, a dielectric field is established between the insulated and the grounded sphere and also between the insulated sphere and the ground plane.

At relatively close spacings, the flux between the sparking surfaces of the spheres is not appreciably distorted by the ground plane; hence, the voltage gradients at the sparking surfaces of the two spheres are equal and the gap does not show any polarity effect.

When the sparking distance is increased beyond a certain value, which the paper shows to be a function of sphere diameter, the ground plane distorts the dielectric field between the spheres to such an extent that the gap becomes electrically unsymmetrical and a polarity effect results. A part of the flux originating on the insulated sphere terminates on the grounded sphere and a part of it on the ground plane. Be-

cause of this flux distribution, the flux density and the resulting voltage gradient is greater on the sparking-surface of the upper ungrounded sphere than on the lower grounded sphere. When the gap spacing is further increased, the flux distortion and the difference in voltage gradient at the sparking-surfaces of the two spheres becomes greater.

When the top sphere is negative, the electrons in the gap are repelled from it toward the bottom grounded sphere. If the voltage gradient is sufficiently high, these electrons will attain ionizing velocities and release more electrons and positive ions by ionizing the air. The newly formed electrons are also repelled and produce further ionization as they travel toward the positive grounded sphere. The original positive ions in the gap and those formed by the avalanche ionizing action are attracted toward the negative sphere, but due to their relatively large mass and resulting low velocity, as compared with the electrons, a positive space-charge results. The maximum ionization and, therefore, the maximum positive space-charge will occur in the region of highest voltage gradient or near the ungrounded negative sphere. This positive space-charge near the negative sphere further increases the gradient and the ionization in that region. As the positive space-charge approaches very near the negative sphere, it probably ultimately produces a sufficiently high gradient to overcome the work function of the metal and extracts electrons from the sphere. Some of the electrons extracted recombine with positive ions, and others are projected into the interelectrode space and sustain the ionization. This ionization process progresses until the entire distance between electrodes is ionized, and spark-over occurs if the spacing of the sphere gap is within the range where the corona-formation voltage and spark-over voltage are identical. Reversing the polarity of the sphere gap, the upper ungrounded sphere becomes positive, and the region of high-voltage gradient resulting from the flux distortion of the ground plane is on the upper sphere as before. The electrons and negative ions are attracted to the top sphere, and the positive ions left behind by the avalanche process of ionization by collision are near the ungrounded sphere as before, but it is now positive instead of negative. Under these conditions, the grounded negative sphere must supply the electrons for sustaining a discharge between spheres. However, the negative sphere has a low voltage gradient at its discharge surface due to the ground-plane flux distortion, and the further fact that the point of maximum positive space-charge is at the point of maximum ionization near the positive sphere. As a result of these conditions, the extraction of the necessary electrons from the negative sphere to sustain a discharge requires a higher voltage when the upper ungrounded sphere is positive than when it is negative. Therefore, at intermediate gap spacings where both corona formation and spark-over occur at the same voltage, the grounded sphere gap sparks over at a lower voltage when the upper ungrounded sphere is negative than when it is positive.

At wide gap spacings, where corona forms on the ungrounded sphere of the grounded gap at a voltage lower than the spark-over value, the characteristics of the gap are materially altered. Under these conditions the sphere gap takes on the characteristics of a gap having electrodes with a very marked dissimilarity. The corona streamers on the top sphere act as points and the bottom sphere and ground plane as a composite electrode. The condition is a compromise between a point-to-sphere and a point-to-plane gap. When the ungrounded sphere is positive, the free electrons are attracted upward toward it and accelerated to the ionizing velocity in the region where the voltage gradient is sufficiently high. These electrons and those liberated by ionization, except the ones lost by recombination, are conducted away by the positive electrode. The relatively immobile positive ions not neutralized by recombination are left along the ionization or corona-streamer paths and form space charges. These positive space charges add to the field from the positive electrode and extend the ionizing gradient at the ends of the streamers to greater distances. In this manner ionization is progressively extended downward at the ends of the corona streamers until either the gradient at the extreme limit of the ionized region falls below the critical value or complete spark-over occurs. When the ungrounded sphere is negative, the free electrons in the surrounding space are repelled downward at high velocity producing ionization by collision in the region that is above the critical gradient. A positive space charge is formed near the negative sphere, and a negative space charge is formed outside of the positive space charge. The field of the positive space charge opposes the field from the negative electrode which it surrounds and reduces the resultant electrode flux in the area outside of the positive space charge. The decrease of flux due to the positive space charge around the negative sphere reduces the distance to which the ionizing gradient extends from the electrode and hence increases the voltage necessary to cause complete spark-over. Therefore, at wide spacings on the grounded sphere gap where corona occurs at an appreciably lower voltage than complete spark-over the gap sparks over at a lower voltage when the ungrounded sphere is positive than when it is negative.

J. R. Meador in his discussion further stresses the importance of adequate clearance around sphere gaps to avoid abnormal flux distortion and the resulting erratic characteristics. That point cannot be emphasized too strongly, because there is no doubt that it is the cause of much difficulty with sphere-gap measurements.

The inconsistencies in the transition from partial negative spark-over to all negative spark-overs found by Mr. Meador in his 1934 investigations, which he points out were particularly pronounced in the case of the 6.25-centimeter sphere gap, merit special consideration. In contrast with Mr. Meador's experience, we have always obtained polarity characteristics for the 6.25-centimeter sphere gap that show consistently a definite range of gap spacings over which the spark-over is 100 per cent negative.

The change from 100-per-cent-negative spark-overs to 80 per cent, when the sparking point of the ground sphere was raised from 4.1 sphere diameters to 5.7 sphere diameters above the ground plate, reported by Mr. Meador, probably is not due to the change in position of the gap with respect to the ground plane.

During the academic year 1933–34, E. D. Harrington and K. M. Klein, students at Oregon State College, made a careful investigation of the influence of the ground-plane position on the polarity characteristics of the 6.25-centimeter sphere gap. The results of their investigations were given in a paper presented before the Portland Section of the AIEE on May 19, 1934. They used a vertical gap with the sparking surface of the grounded sphere at various distances ranging from 1 to 20 diameters above a large metal ground plate. The polarity characteristics, over this entire range of ground-plate positions, each showed a definite range of gap spacings over which the spark-overs were 100 per cent negative. The 100-per-cent-negative spark-over range was changed to some extent by the position of the ground plane, but typical polarity characteristics with four distinct polarity ranges were obtained for all ground-plane positions.

In 1935, polarity characteristics were taken for a 6.25-centimeter horizontal grounded sphere gap. The characteristics were taken with the horizontal axis of the spheres at both four and five diameters above the ground plane. This horizontal gap also had typical polarity characteristics with the usual four distinct polarity ranges.

For the past eight years, the polarity characteristic of either a 6.25-centimeter or a 12.5-centimeter vertical sphere gap has been taken each year by students as a high-voltage laboratory experiment. These polarity characteristics have always shown a 100-per-cent-negative spark-over range and have been typical in every respect.

In view of this evidence, we are forced to the conclusion that Mr. Meador's failure to find a range over which the spark-over of the 6.25-centimeter gap was 100 per cent negative was due to some extraneous cause not directly related with the polarity characteristics of the gap.

It has been found that it is necessary to have the circuit free from corona discharges of any magnitude when the polarity characteristics are taken on small sphere gaps. The elimination of corona is important because corona discharges cause transient disturbances in the voltage that alter the polarity distribution of spark-over on small gaps. It is possible that either corona or some other electrical disturbance may account for Mr. Meador's failure to secure any 100-per-cent-negative spark-over range on the 6.25-centimeter sphere gap.

The shielding effects of wires reported by Mr. Meador are very interesting and are in agreement with the results obtained by George M. Chandler in his thesis "The Control of Sphere-Gap Polarity Characteristics" submitted at Oregon State College in 1935. Mr. Chandler used one toroidal shielding ring around the upper ungrounded sphere and in various vertical positions with respect to it, and also two toroidal rings with one around each sphere of the gap. He found that one shielding ring properly adjusted around the ungrounded sphere was adequate to eliminate the polarity effect.

Devices for Controlling Amplitude Characteristics of Telephonic Signals

By A. C. NORWINE
NONMEMBER AIEE

Synopsis: This paper describes a family of devices which automatically respond to signals and control the circuit amplification in such a way as to improve transmission. Their general characteristics are outlined, their differences explained, and some of their applications are listed.

THE transmission of speech energy over electrical circuits is attended by the interesting and sometimes difficult problem of preserving the original signal in spite of limitations in the transmission medium. These limitations include load-carrying capacity, interference with other service, noise, change in attenuation with time, and many others. Because of special limitations it is sometimes desirable to alter the amplitude characteristics of the speech or other signal energy without, of course, materially lowering its intelligibility. In high-quality systems the peak voltage from some speech sounds of a given talker may be over 30 decibels (some 30 times) higher than from his weakest sounds when there is very little inflection in the speech. Loudness changes for emphasis will increase this range of intensities. Ordinary message systems do not have to contend with quite so wide a range of instantaneous voltages from a single talker, but different talkers under extreme terminal conditions produce about a 45-decibel range of average voltage, which is additive to that for a single talker. Consequently, a voltage range of about 70 decibels (over 3,000 to 1) must be considered for message circuits.

In order to accommodate such ranges of intensity to certain transmission media such as radio links a new family of automatic devices has been developed. In general all of these contain amplifiers or attenuating networks whose loss or gain is changed according to some function of the applied input and which may have a variety of time sequences in their control circuits. It is hoped that by the classification and description of some of these devices their distinguishing characteristics and fields of usefulness will be made somewhat clearer. We are to be concerned here principally with those elements allied to the telephonic art, although some applications are to be found in other fields. It is not intended to include those voice-operated functions which are essentially switching operations although the distinction in some cases becomes exceedingly fine.

Names of volume-controlled devices* which have been used in published papers include vogad,[†2–4] compandor,[*5,6] and volume limiter.[†] Without direct comparison it may not be obvious how these and similar devices differ. First the apparent similarity of several of these devices will be shown in simple diagrams. Next the more important characteristics of a number of devices will be presented in tabular form, followed by descriptions of the different types. These will then be discussed with particular emphasis on their distinctive qualities, with notes on their variants which have some apparent value.

General Characteristics of Volume-Controlled Devices

In figures 1 to 10 are shown simplified diagrams of some of these devices. While detailed descriptions of them will be deferred till later it may be pointed out that all those shown contain "vario-lossers," and all have paths from the main transmission path to control circuits which affect the vario-losser. A vario-losser usually consists of a balanced pair of vacuum tubes whose gain is changed by varying the grid bias or a network of non-linear elements such as copper oxide or silicon carbide whose loss is changed by varying a current through them. In some special cases it may be a mechanically adjusted variable network. The word "vario-losser" is thus a generic term relating to a circuit whose loss or gain is controllable. A control circuit ordinarily consists of an amplifier and rectifier whose d-c or a-c output bears a chosen relation to its input. Thus some control circuits are marginal; they produce no control voltage till the input exceeds some critical value, then produce large control voltages for small additional increments of input. These are used, for example, when it is desired to limit the output of a vario-losser to a definite amount. Another type of control circuit produces a current or voltage which is linear with input expressed in decibels. In combination with a vario-losser whose gain is a linear function of control current or

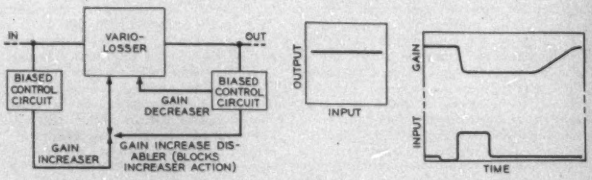

Figure 1. Vogad

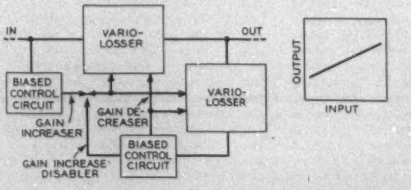

Figure 2. Half vogad

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2. For all numbered references, see list at end of paper.

* See the footnote on page 63.
† "Volume-operated gain-adjusting device."
** A combination of the names *compressor* and *expandor*.

Table I—Characteristics of Volume-Controlled Devices

Device	Gain Controlled by	Frequency of Adjustment	Time Required for Gain Changes		Ratio of Output Range to Input Range**	Position of Controls	Volume Range Controlled*	Frequency Range Controlled	Frequency Range Causing Control	Part of Input Range Causing Operation
			Gain Increase	Gain Reduction						
1. VOGAD	Average volume	Infrequent. Gain fixed between transmissions	After a few words —sometimes eight to ten words	After one or more words	Approximately 0	At input and output	Large	Full band transmitted	Full band	All
2. VOLUME LIMITER	Average volume over part of input range	Relatively infrequent. Approaches maximum gain in silent periods.	Slow and continuous	After one or more words	1 up to operate point, 0 above	At output	Moderate	Full band	Full band	High amplitude only
3. COMPANDOR a. Compressor } b. Expandor }	Syllabic variations	Continuous at syllabic rate	On each syllable	On each syllable	1/2 to 1/5 5 to 2	Compressor output } Expandor input }	Large	Full band	Full band	All
c. Special compandor	Syllabic variations	Continuous at syllabic rate	On each syllable	On each syllable	1/2 to 1/5 5 to 2	Compressor output expandor input or expandor control over separate channel	Large	High frequency only or multi-band	High frequency only or multi-band	All or high amplitude only
4. RADIO-NOISE REDUCER (Limited-range expandor)	Syllabic variations over part of input range	Each syllable	On each syllable	On each syllable	2 for low amplitudes. 1 for high.	At input	Moderate	Full band	Full band	Variable at low amplitudes only. Fixed gain to high amplitudes
5. LIMITED-RANGE COMPRESSOR	Syllabic variations over part of input range	Each syllable within the operating range	Fast	Fast	1 up to operate point, then 0 to 1/2, then 0	At input or output	Small	Full band	Full band	High or intermediate amplitudes
6. PEAK LIMITER	Syllable peaks	Infrequent	After about one word	On single syllable	1 up to operate point, then approaches 0	At output	Small	Full band	Full band	High amplitude only
7. PEAK CHOPPER	Instantaneous peak voltage	Relatively infrequent	Instantaneous	Instantaneous	1 up to operate point then 0	At input	Very small	Full band	Full band	High amplitude
8. CROSS-TALK SUPPRESSOR	Voltage exceeding a specified value low in input range	Relatively frequent	Fast	After one or two words	1 except at point of discontinuity	At input	Very small	Full band	Full band	All above specified low value
9. ROOTER AND INVERSE ROOTER	Instantaneous voltage	Continuous	Instantaneous	Instantaneous	Ordinarily 1/2 and 2	Integral with vario-losser	Moderate	Full band	Full band	All

* Outside these ranges most of the devices tend to be linear transducers except for higher volumes applied to "limiters."

** It is important to note that these ranges are measured in the same units as the respective control circuits measure; *viz.*, "volume," "syllabic power," "voltage," etc.

voltage one can produce a device whose gain is a linear function in decibels of the input to the control circuit.

It will be recognized that if the application or removal of the control energy is retarded, the action of the control circuit may be made quite different on transient inputs than on steady-state inputs. It will appear later that this is the important distinction between some of the devices to be discussed and that fundamental differences in their functioning are thus brought about.

Referring to the figures once more it will be noted that some control devices are connected to the transmission path at the input to the vario-losser. These are known as "forward acting" control circuits. Other controls, connected at the vario-losser outputs, are known as "backward acting" control circuits. This is simply convenient terminology to indicate whether the control energy is progressing in the same direction as the main transmission or is progressing in a backward direction after traversing the main path, usually through a vario-losser. Some backward-acting controls function to measure the output of the devices containing them and to make whatever adjustments are required. Others are placed in that position to take advantage of the vario-lossers in the transmission paths, i.e., such controls could be replaced by combinations of forward-acting controls and extra vario-lossers.

In table I, nine of the volume-controlled devices* which have been developed for various commercial and experimental uses are listed with the functions of voltage, time, and frequency which are employed to obtain their respective performances. There is, of course, some latitude in the choice of these functions for any one device. Pending more complete description of the different types in the following paragraphs this table should be viewed as illustrating the general character of the different circuits and also the range of the variables which already have been employed. For example, it will be seen that instantaneous voltage of the signal wave, its short-time average value, peak power, syllabic variations, and long-time average power have all been used as criteria of gain settings in different circuits. Some devices change their adjustments only when critical values or ranges are exceeded, while others vary

* The names employed do not follow an entirely logical classification, but they are given here because they have had considerable usage. For the same reason the term "volume-controlled devices" is used, although to be strictly correct it might better be "sound-energy-controlled devices," for example, for not all the devices operate in accordance with "volume" as measured by the well-known class of visual-reading meters called "volume indicators."

somewhat with every syllable if speech, for example, is being transmitted. Some are linear transducers to all but low or high amplitudes while others reduce or increase the output range from that at the input. It will be seen that proper choices of times for gain increase and gain decrease in combination with certain gain-control criteria make possible a wide variety of signal-altering means to meet different requirements.

Description of Devices in Table I

With this introduction to the combinations of characteristics which are possible it should be less difficult to distinguish between the specific devices discussed in the following paragraphs, which in addition to describing the devices, contain some comments which should assist in visualizing their forms and their operation.

1. The *vogad* (figure 1) is a device which will maintain at its output speech volume[1] which, over a certain range of input, is relatively independent of the speech volume applied to its input and which, in the ideal case, will not change its gain during periods of no speech input. It makes little or no alteration in the ratios of maximum and minimum instantaneous-to-average voltages of the speech.

2. The *volume limiter* (figure 3) is a device which is a linear transducer for all speech volumes up to a critical value, beyond which all input volumes produce essentially the same output volume. It is essentially different from the vogad in that its gain approaches the maximum value when input is removed.

3. The *compandor* (figures 4 and 5) is composed of a *compressor* and an *expandor*. A *compressor* is a device whose input-output characteristic on a decibel scale has a slope less than unity* and whose gain or loss is variable under control of the input energy at a time rate which will permit it to follow the syllabic rate of change of speech energy. Similarly, an *expandor* is a device whose input-output curve has a slope greater than unity and whose gain is variable at a syllabic rate under control of the input energy. Thus very shortly after all input is removed the gain of a compressor is maximum and the loss of an expandor is maximum. The reciprocal of the compressor characteristic slope is spoken of as the compression ratio, and the slope of the expandor characteristic is spoken of as the expansion ratio.

4. The *radio noise reducer*[2,3] (figure 6) combines the functions of an expandor which operates in the range of amplitudes where noise and weaker speech sounds lie and a linear transducer which comes into play for all amplitudes exceeding a critical value, which can be set to best suit the atmospheric noise conditions. In other words, the radio-noise reducer is a limited-range expandor. Inputs which are below the expandor range are subject to transmission at the minimum gain.

* That is, if the input increases by x decibels the output increases by less than x decibels.

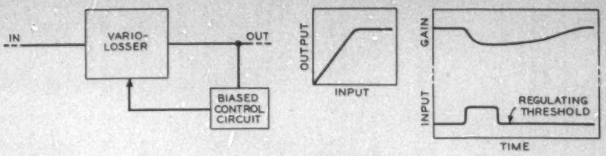

Figure 3. Volume limiter

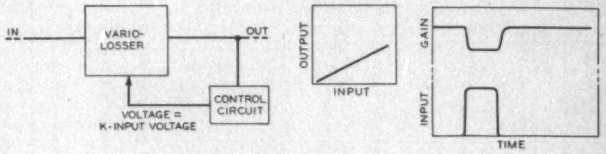

Figure 4. Compressor

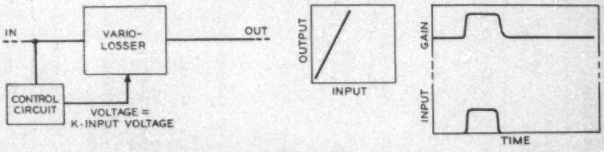

Figure 5. Expandor

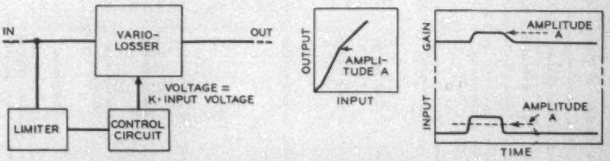

Figure 6. Limited-range expandor

Radio-noise reducer

5. The *limited range compressor* (figure 7) is a device whose operating range includes a region within which compression at a syllabic rate can take place; at other inputs the device is a linear transducer. Its connecting diagram and time functions are the same as those shown in figure 5 except that the control circuit contains a limiting device, so that compression takes place in only a portion of its input range, analogous to the action of the limited-range expandor of figure 6. As a special case the *limited range compressor* may have no linear range above its compression range, thus becoming one type of peak limiter.

6. The *peak limiter* (figure 8) is a device whose gain will be quickly reduced and slowly restored when the instantaneous peak power of the input exceeds a predetermined value. The amount of gain reduction is a function of the peak amplitude, and in practice is usually intended to be small to prevent material reduction of the range of intensity of the signal.

7. The *peak chopper* (figure 9) is a device which prevents transmission of peak amplitudes exceeding a critical amount, an essential characteristic being that the loss it inserts is completely determined by the instantaneous voltage of the signal; that is, its operating and releasing times are substantially equal to zero.

8. The *cross-talk suppressor* (figure 10) is a device which normally presents a prescribed loss to transmission, which loss is removed rapidly when the input amplitude exceeds a certain threshold and is reinserted at a definite time after the input is removed. It reduces low-amplitude unwanted currents such as cross talk but does not affect amplitudes in the useful signal-voltage range. This device differs from the limited-range expandor in that the time during which the low-loss condition is maintained is considerably greater, so the transition from one gain to the other occurs less frequently.

9. A *rooter* is an instantaneous compressor. Such a circuit can be made to produce an output whose instantaneous voltage is, for example, the square root or some similar function of the instantaneous voltage applied to the input. An *inverse rooter* is an instantaneous expandor whose characteristic is complementary to that of the rooter. A combination of *rooter* and *inverse rooter* will reduce the load requirements on a trans-

mission system between the two units but requires that it transmit a wider band of frequencies than that for the original signal, and that it be essentially free from phase distortion. This does not seem to be an attractive arrangement from a commercial viewpoint and is included here simply as an illustration of one of the possible modifications of signal energy. It is not shown in the group of diagrams.

Variants to the Devices Described

In addition to these there are various devices which are essentially modifications of those described. For example, a half vogad, figure 2, may have the same time functions as a vogad, figure 1, but the gain changes in the transmission circuit are half as great for the same range of input volumes. Thus in a vogad the range of gain changes in the transmission circuit is equal to the range of input volumes, so that the output volume is the same for all input volumes. In the case of the half vogad the range of gain changes in the transmission path is one-half the range of input volumes, so the output volume range is one-half that of the input. It is also possible to construct a vogad whose output volume range is any desired fraction of the input range. As another example of modification of the devices described, for special applications it may be desirable to incorporate a certain amount of syllabic compression in a vogad.

Communication circuits which have separate paths for oppositely directed transmission between the two terminals are usually operated at such an over-all loss that with ordinary terminations there will be little tendency for circulating currents to build up to a "singing" condition. Sometimes there may not be a great deal of margin, however, so that volume-controlled devices added to such circuits must add loss at some point to counterbalance whatever gain is put in at some other point. Thus a vogad inserted at the transmitting side of one terminal of such a circuit to amplify speech energy from weak talkers must be supplemented by a "reverse vogad" in the receiving side of the circuit. The reverse vogad is simply another vario-losser which is operated upon by the vogad control circuit in such a way that it always has a loss numerically equal to the gain of the vogad. Any vogad gain will be compensated by the reverse-vogad loss, so no greater tendency to sing will be effected by the addition of the combination to the circuit. In like manner half vogads must be used with compensating reverse half vogads.

Combinations of some of the devices also have interesting characteristics. For example, a combined radio-noise reducer and peak limiter at the receiving end of a circuit would suppress noise and would also reduce the amplitude of excessively high amplitude signals. Likewise, a vogad, compressor, and peak chopper in tandem in the order named could be made to reduce the range of input signals by a very large amount for transmission over a medium having only a small range between noise and maximum permissible signal. In this case it would be practically impossible to recover the original signal range at the receiving terminal of the medium, but the intelligibility of speech over such a system has been shown in the laboratory to be good.

Special compandors for high-quality service may require compression and expansion which varies with frequency. The exact characteristics will depend upon band width, program material, and transmission medium. For transmission media in which the noise reproduced at the receiving end is principally at the higher frequencies an unusual effect is obtained if the usual variety of compandor is used. Low frequencies unaccompanied by high frequencies will cause a gain change in compressor and expandor, thus changing the background of high-frequency noise which is not masked by the low-frequency signal energy. The resulting swishing noise has been given the onomatopoeic name of "hush-hush effect." To avoid this, recourse may be had to split-band compandors in which the compression and expansion is done only at high frequencies or separately for low and high frequencies. The successful application of the latter method is, however, more difficult than it appears from its simple description.

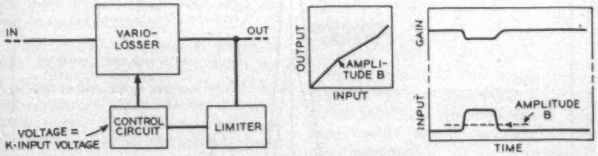

Figure 7. Limited-range compressor

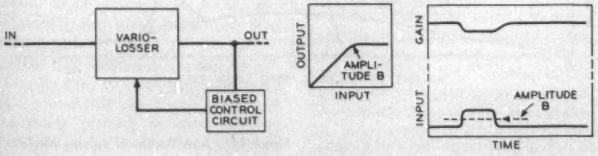

Figure 8. Peak limiter

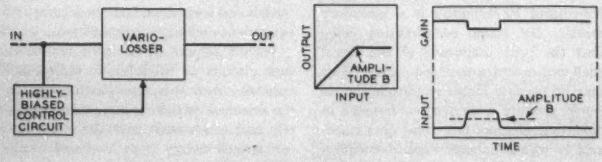

Figure 9. Peak chopper

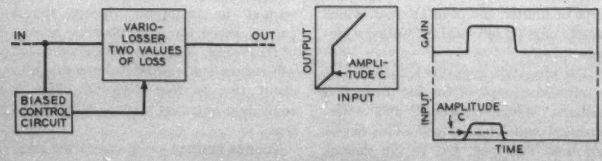

Figure 10. Cross-talk suppressor

Distinguishing Characteristics

It is important to distinguish between the half vogad, figure 2 and the compressor, figure 4. As shown in table I the latter operates on syllabic variations and

the former on the average volume of the input. Thus the half vogad reduces the range of output volumes to one-half that at the input while the compressor reduces the range of syllabic power at its output to one-half that at the input. In other words, the compressor reduces the ratio of peak to average power on constant-volume speech, while the half vogad simply adjusts for that volume and does not alter the peak ratio. There is, of course, the additional important difference that the half vogad retains its gain setting during silent periods while the compressor, by virtue of having followed the syllabic power, has its maximum gain during silent periods.

Volume limiters, figure 3, may be mistaken for vogads, figure 1, because during speech input above a certain value the two may produce the same output volume. They both employ something like a measurement of average power over periods longer than a syllable to determine their gain settings. The important difference is that a vogad retains its gain setting when speech currents are not present, while a volume limiter approaches its maximum gain during such periods. In terms of the output resulting from a range of input volumes there is another important difference if the volume limiter operates over only part of the input range: the vogad reduces the width of the distribution curve of volumes to a very small value, while the volume limiter moves all the area under the distribution curve above a certain point to the region near that point, which is its limiting volume. This is illustrated in figure 11, in which the calculated modifications of a volume distribution by a vogad and by a volume limiter are shown.

In the cases "without volume control" and "with a vogad" the distributions are normal, and the standard deviation, σ, has its usual statistical significance. With a volume limiter, only volumes above the limiting volume are affected, and these higher volumes are redistributed according to a normal law whose standard deviation is one decibel, as stated in the figure.

It is also important to distinguish between a peak limiter, and a peak chopper, figures 8 and 9. Naturally they resemble one another since they are intended to permit transmission of signals at higher average amplitudes without excessive loading of transmission circuits. However, they are intended for different classes of service and hence are not interchangeable except in some borderline cases. For the highest grade of transmission harmonic production must be negligible and the reduction in amplitude range of signals small and infrequent. Gain changes must be smooth, though rapid enough to compensate for practically any input wave to be expected. These characteristics are found in the peak limiter now being furnished for use on program networks and radio transmitters.[10,11] For services in which it is desirable to maintain the signal energy at a high value to override noise and in which harmonic distortion must be kept low a peak limiter with somewhat smaller time constants may be used. A high-ratio limited-range compressor might be suitable in this instance. This device would lower its gain a little more quickly on excessive inputs, and it would also reinsert its gain much more quickly; it would affect the naturalness of the sound of the signal more than the slower peak limiter but it would also cause the signal to override noise somewhat better. In a third variety of service the harmonic distortion introduced by a limiter is a secondary matter, the prime consideration being that the peak amplitude of the signal shall not exceed a specified value. This may be because higher-amplitude signals would produce a tremendous increase in distortion or cross talk into other channels or would damage expensive equipment farther along in the circuit. For these cases we may use the fastest possible type of limiter, the peak chopper, which simply cuts off any peak exceeding a certain value.

The cross-talk suppressor, figure 10, is a splendid example of the fine distinction between volume-controlled and voice-operated switching devices. This device has been described, but in the present state of the art its time functions have not been definitely fixed. If the characteristic of loss versus input is made steep enough and the speed of operation fast enough it will sound like a switching circuit and may in fact be replaced by a relay-switched attenuating network. If made somewhat slower and given a smaller slope of loss versus input it approaches the limited-range expandor or noise reducer.

Applications and Expected Advantages

It may be of interest to give some approximate figures on the magnitudes of the advantages to be obtained by the use of some of these devices. It will be understood that the values to be given are simply illustrative, some having been obtained from field service on particular models and some from tests on laboratory equipment under special conditions.

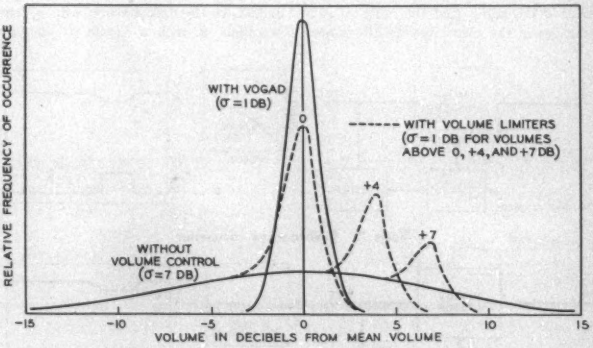

Figure 11. Modification of volume distribution by use of a vogad or a volume limiter

Vogads appear to be most useful in such circuits as transoceanic radio connections, where it is important to operate the terminal switching equipment properly and to transmit over the radio circuit speech energy from loud and weak talkers equally well. It is essential in such cases that noise should not be increased in amplitude during speech pauses, hence the gain retaining feature of the vogad. On such a circuit a vogad will reduce a 45-decibel volume range to about two to four decibels. This is equivalent to expert manual volume control.

Volume limiters are in use at the present time to prevent peaks of speech

energy in carrier circuits from "splashing" into telegraph channels.[7] Some five- to ten-decibel limiting is allowed on loudest talkers, which causes little degradation of the speech channels but makes possible the use of telegraph on the same carrier system. There is no widespread use of volume limiters in point-to-point radio service so far, but in cases in which there is no disadvantage in raising noise in silent periods of speech, such as in push-to-talk installations, proper transmitter loading can be obtained with volume limiters fairly cheaply.

One commercial model peak limiter, used as part of a program amplifier[10,11] is capable of introducing a considerable amount of compression without overloading on peaks, but for the preservation of adequate program volume range it is being recommended that only three-decibel peak limiting be allowed. This, of course, reduces the range of intensity of the program, but from the standpoint of the listeners it is equivalent to doubling the transmitted power or obtaining the same signal-to-noise ratio with half the transmitted power.

Limited-range compressors might be used either on land lines to insure full loading or on radio links whose fading is too severe to permit the use of normal compandors. There is no commercial application of either sort at the present time. Peak choppers are, however, used on some high-power radio transmitters which might otherwise be temporarily disabled by high peaks in the signal being transmitted.

The chief usefulness of compandors is on radio links in which the transmission of a compressed signal with subsequent expansion permits operation through higher noise or with lower transmitter power. On a long-wave transatlantic radiotelephone circuit a compandor with 40-decibel range has been shown to allow an increase in noise of some five decibels before reaching the commercial limit.[6] With smaller amounts of noise the noise advantage of the compandor approaches half its range in decibels. This benefit is sometimes applied to a reduction of transmitter power.

Radio noise reducers have been used to advantage in connection with short-wave ship-to-shore and transoceanic radiotelephone service. In the former, routine transmission rating is given on a judgment basis using a merit scale from one to five, five being practically perfect transmission and one so poor that intelligibility is very close to zero. It will then be seen that the observed improvement of one-half to one point in transmission rating due to the noise reducer is of considerable importance. Perhaps more graphic figures are those for transoceanic service, where the reduction of noise in the receiving path not only reduces the noise heard by the listener but also improves the voice-operated switching with the indirect result that at times receiving volume increases of 5 to 15 decibels are realized.[9]

As has been noted, the radio-noise reducer is a special use of an expandor alone. There are also two interesting applications for a compressor alone. The first, which uses a fairly high ratio of compression, has been mentioned as one type of peak-limiting device. The second, using a moderate ratio of compression, is in connection with announcing systems for use in very noisy locations. Its effect is to amplify weak sounds more than strong sounds, which considerably improves the intelligibility through high noise. For quiet locations it is of less value, since the speech sounds lose some of their naturalness in this process.

Conclusion

In the course of developing various types of the volume-controlled devices which have been described means have been worked out for providing almost any combination of time constants, range of control, and other characteristics which may be required. Some devices for which there were specific commercial applications or useful functional characteristics for experimental work have been constructed, with resulting advantages which have been briefly mentioned. There remain many possible ways to alter the characteristics of signal energy such as speech to which these methods are applicable and which await the special needs of new transmission problems.

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Testing and Application of Lightning Arresters

FOR some time, information dealing with the testing and application of lightning arresters has been needed. The two memoranda presented herein entitled "General Guide for Utilities on Methods of Testing Lightning Arresters" and "Factors Affecting Application of Arresters" have been prepared by the lightning arrester subcommittee* of the AIEE protective devices committee and provide such information.

†General Guide for Utilities on Methods of Testing Lightning Arresters

At the meeting of the AIEE lightning arrester subcommittee in New York, January 1937, it was decided that general information regarding methods of testing lightning arresters should be prepared. It was proposed that utilities make tests on new arresters, arresters removed from lines and accumulated in stock in a routine manner, and arresters in service, in order to determine the ability of such arresters to perform satisfactorily in service, as well as to augment, as much as possible, the somewhat limited amount of information now available on the subject of test limits.

The scope of this guide is mainly limited for the present to line-type arresters rated at 15 kv and less, such devices being constructed in accordance with the usual ideas of arresters, that is, with characteristic element having valve action against follow current in series with a gap or set of gaps.

It is desirable to obtain information on test methods, results, and characteristic limits for line and station type arresters rated above 15 kv, in order that this guide may later be expanded to include detailed information on preferred test methods and limiting values for all types and ratings of arresters. In the meantime for arresters rated above 15 kv, it will usually be preferable to obtain the assistance of the manufacturers in connection with the test methods to use and the interpretation of test results.

It is expected that, after more experience is obtained, the outline of test methods and the data on test limits will be expanded and improved as information becomes available.

Impulse Tests

Impulse tests are used to determine the surge protective characteristics of arresters, while 60-cycle tests indicate the internal condition of arresters and the relation of breakdown voltage to rated voltage. Impulse tests on new and used arresters should follow, in general, the test method prescribed in AIEE Standard No. 28. To determine the condition of the arrester when new or when removed from service, an impulse should be applied to the arrester and breakdown and impedance drop voltages obtained by means of a cathode-ray oscillogram. These values should be compared with corresponding values for new arresters as given for 3- to 15-kv arresters in the paper "Distribution Lightning Arrester Performance Data," ELECTRICAL ENGINEERING, May 1937, page 576, or as furnished by the arrester manufacturer for all ratings.

To determine the ability of an arrester to operate satisfactorily in service without change in its characteristics, the AIEE standard operating-duty test (AIEE 28-234) should be applied. As this test requires that the arrester be subjected to 60-cycle voltage during the application of impulses, it may be feasible to make such tests while the arrester is connected to the lines.

60-Cycle Tests

TEST CIRCUIT

Three suitable circuits for conducting tests at 60 cycles on arresters are illustrated in the attached figure 1. These circuits are essentially similar, comprising means for applying a variable voltage up to the breakdown voltage of the arrester, and meters for indicating the voltage applied to, and leakage current through, the arrester. An essential part of the test set is a current-limiting resistor R_1, located in either the low-voltage or high-voltage side of the test circuit, of such value as to limit the current during breakdown to a value which will not damage the arrester. Limiting values of from 3 to 15 milliamperes through the arrester

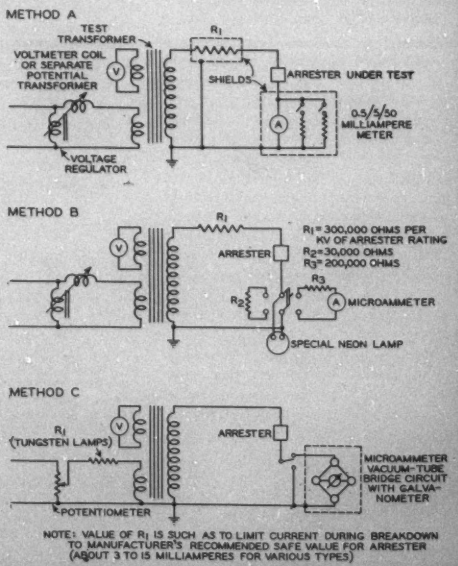

Figure 1. Circuits for 60-cycle tests of lightning arresters

Paper number 38-43, recommended by the AIEE committee on protective devices and presented at the AIEE Pacific Coast convention, Portland, Ore., August 9–12, 1938. Manuscript submitted December 27, 1937; made available for preprinting April 12, 1938.

† Prepared under the sponsorship of Herman Halperin.

* Personnel of the AIEE lightning arresting subcommittee: J. R. North, *chairman*; H. W. Collins, R. H. Earle, I. W. Gross, Herman Halperin, C. F. Harding, K. B. McEachron, J. R. McPartlin, A. M. Opsahl, A. H. Schirmer, H. K. Sels, L. C. Smith, A. H. Sweetnam, and J. J. Torok.

have been used or suggested. For the test circuit shown as method *B*, the limiting leakage current during breakdown may be as low as three milliamperes. For testing arresters with different voltage ratings, the resistance should be variable or provision made for the insertion of resistors of proper values.

For methods *A* and *B*, the drop of voltage in the resistor R_1 in the circuit directly including the arrester should be taken into account in determining the voltage across the arrester.

Control of the test voltage may be accomplished by either a regulator or a potentiometer. If a voltmeter coil in the test transformer or a separate potential transformer is used to measure the applied voltage, the voltmeter should preferably be calibrated against the crest voltage applied to the arrester, but should give readings of root-mean-square values of the equivalent sine wave.

In one of the circuits shown, a neon tube is used to detect breakdown; the others use the voltmeter or microammeter indication. For the latter case the meter should be able to withstand the current during breakdown without being damaged. This meter, to accomplish its primary purpose of measuring leakage current through the arrester, should have a range of from about 10 microamperes to 3 or 5 or 15 milliamperes.

Care should be taken that stray electrostatic fields or capacitive currents do not affect the leakage current measurements. This may be prevented by suitable shielding, as indicated in two of the sketches, or by physically isolating the microammeter and arrester from each other and from the remaining testing equipment. If desired, the arrester under test may itself be shielded by placing it in a grounded metal box.

Test Procedure

1. In 60-cycle tests, there must be no other voltage on the arrester than the test voltage. This means that, for arresters installed on the system, the arrester must be disconnected from the lines before being tested for breakdown voltage.

Sixty-cycle leakage current measurements at operating voltage, however, can possibly be made on the arrester as installed. Due to the necessity for careful shielding against stray fields, such testing of arresters in service should be considered as developmental work and investigated by each utility planning tests on installed equipment.

2. With the microammeter in the test circuit, the leakage current through the arrester is usually measured at the rated voltage of the arrester.

3. The microammeter is either cut out of the circuit or shunted by resistance. The test voltage is then gradually increased to the breakdown point of the arrester. The breakdown voltage and breakdown characteristic (whether sharp or gradual) are indicated by the neon lamp, if used, or by the voltmeter or shunted microammeter.

Suggested Test Limits

Insufficient data are as yet available to indicate sharply the test limits differentiating between satisfactory and unsatisfactory arresters removed from service. For satisfactory three-kv line type arresters, one utility has found from its experience and examinations of used arresters that the upper limit of leakage current should be about 150 microamperes at the normal operating voltage, that is, 2,300 volts. For other voltage ratings, this value might be subject to modification because of varying ratios of test (or operating) voltage rating. Further work seems necessary to establish proper values for all voltages.

Arresters of modern manufacture generally have 60-cycle breakdown values between 1.5 and 3.0 times the rated arrester voltage. These ratios result in the limits shown in table I.

Table I

Rated Voltage (Kv)	Usual Limits of 60-Cycle Breakdown Voltages (Kv-RMS)	
	Minimum	Maximum
3	4.5	9
6	9	18
9	13.5	27
12	18	36
15	22.5	45

Due to the differences in designs, it will probably be desirable to determine the ratios for each manufacture, type, and vintage of arrester.

It has been found occasionally for modern arresters, especially for some removed from service, that the 60-cycle breakdown voltage for satisfactory arresters has been outside the limits given in the above table. In such cases the variation is usually on the low side; that is, the 60-cycle breakdown was found to be 1.2 to 1.4 times the rated voltage.

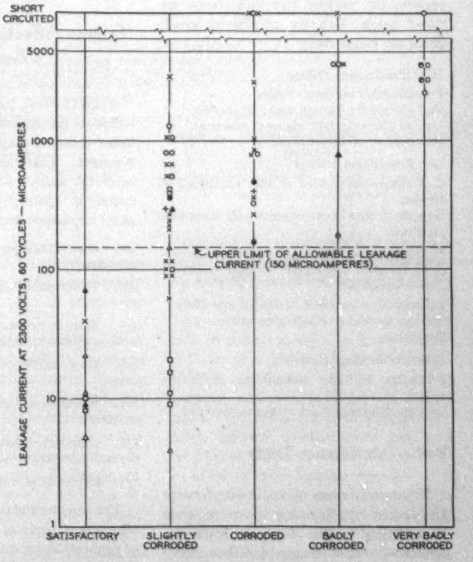

Figure 2. Comparison of leakage currents of used three-kilovolt arresters with condition of gap found on examination

Each symbol represents a different type of arrester

For arresters of older designs, the limits of 60-cycle breakdown voltages have been found for apparently satisfactory arresters to vary between 1.1 and 3.5 times the rated voltage. Usually, however, the test limits have been between 1.5 and 3 times the rated voltage. The outstanding exception, however, has been reported for some old three-kv arresters of two types where the breakdown voltage for apparently satisfactory ar-

resters has been found to be as high as about five times the rated voltage.

In order to set up adequate test limits, both for leakage current and for breakdown value, which may be used to differentiate between satisfactory and defective arresters, it is suggested that each utility, in the preliminary stages of its 60-cycle arrester testing, conduct an investigation on the various classes of arresters removed from service. The recommended procedure is to test each arrester, then dissect particularly those having suspicious test values, and inspect for internal defects. The attached figure 2 indicates the procedure followed by one utility, for example, in determining the proper maximum limit of leakage current for three-kv line-type arresters. The values given above for breakdown voltage limits should also be checked in a similar way and modified, if necessary.

As a guide in analyzing the data obtained in examinations of dissected arresters, the various test indications are listed below with the conditions which generally cause them:

High Breakdown Voltage

Fundamental arrester design.
Gap electrodes burned away in service.
Loss of characteristic element material.
Destruction of internal parts.

Low Breakdown Voltage

Gap electrodes welded or short-circuited in service.
Gap electrodes short-circuited by corrosion products.

Unsatisfactory Discharge Action on Breakdown (gradual breakdown, or high resistance after breakdown)

Fundamental arrester design or assembly.
Change in characteristic element.
Corrosion.

Excessive Leakage Current

Corrosion of gap assemblies (principal cause).
Gap electrodes welded or short-circuited.

Radio-Interference Tests

If frequent cases of radio interference are caused by lightning arresters, then in addition to the 60-cycle tests described above, it is suggested that radio-interference tests be made on arresters with rated voltage applied. Tests should be made in accordance with Edison Electric Institute Publication No. C-9 "Methods of Measuring Radio Noise."

Correlation of Surge and 60-Cycle Data

In order to determine whether any correlation exists between surge data, 60-cycle data, and arrester condition, it is suggested that, where facilities are available, arresters be tested by both methods. The greatest amount of information is to be obtained by testing arresters which are to be dissected for examination.

Co-ordination of Data

Data covering the testing experience of each utility should be forwarded for co-ordination to the subject committee sponsor, Herman Halperin, Commonwealth Edison Company, Chicago, Ill. Such data should include the following: testing circuits and methods, limits of and detailed data used in arriving at limits of acceptable test characteristics, correlation of surge and 60-cycle data, and general test results and conclusions. It is also desirable to follow and report on the protective performance obtained in service with used arresters which were tested before reuse.

*Factors Affecting Application of Arresters

A great deal has been published in technical papers and manufacturers' bulletins about the application of lightning arresters. There are a number of factors involved, many of which have been discussed in other papers. Some of these more important factors are:

(*a*). Characteristics of equipment to be protected.

(*b*). Performance characteristics of arresters.

(*c*). Margin between arrester performance and equipment characteristics.

(*d*). Deterioration of arresters and equipment.

(*e*). When to use line-type or station-type arresters.

(*f*). Influence of circuit feet between arrester and equipment to be protected.

(*g*). Influence of multiple arresters.

This memorandum deals only with the selection of arrester ratings and methods of connection for distribution transformer protection. Certain factors such as when to use line-type versus station-type arresters, influence of distance between arresters and protected equipment, and influence of multiple arresters, are largely matters of individual application.

Selection of Arrester Rating

The principal factors that should be considered in the selection of the rating of a surge protective device, such as a lightning arrester or a gap, are:

(*a*). The maximum dynamic voltage which may occur between sound phase and ground under any fault conditions. The device should withstand this voltage without failure.

(*b*). The efficacy of the protective device in maintaining a low protected level and at the same time meeting satisfactorily the system operating requirements. The impulse volt-time characteristics of the device must be below that of the equipment to be protected.

(*c*). The surge current which must be satisfactorily discharged. The thermal ability of the device must be adequate for the currents expected, and the voltage drop across the arrester during discharge must be sufficiently low to provide satisfactory protection.

The voltage rating of an arrester represents the maximum dynamic voltage which the arrester can withstand continuously and which it can interrupt after functioning. The arrester rating must be not less than the maximum dynamic voltage which may occur between the arrester terminals during disturbances, allowing for the power system neutral being isolated, or grounded, as the case may be, and considering the actual maximum operating voltage. Allowance must also be made for the voltage recovery rate and any overvoltage conditions which may exist due to the overspeeding of hydroelectric generators, etc. The protection afforded by a lightning arrester is approximately proportional to its voltage rating and, therefore, it is important to use an arrester of as low a voltage rating as possible.

The normal "full voltage" rated arrester is designed to operate on an ungrounded or isolated neutral system where the voltage existing between line and ground may at times equal the normal line-to-line voltage. The arrester rating selected is generally five per cent or more above the maximum operating line-to-line voltage. Under favorable conditions where the system neutral is effectively grounded, better protection can be obtained by the use of an arrester having a reduced voltage rating, provided the upper limit of dynamic voltage of the arrester is not exceeded under any operating or fault condition. In the past, "grounded neutral" arresters have had voltage ratings approximately 80 per cent of the "full rated" arresters. This gave a wide margin above the normal system line-to-neutral voltage but a margin which is required to allow for fault voltages, etc.

For the purpose of determining the allowable arrester voltage rating, the

*Prepared under the sponsorship of J. R. North.

maximum dynamic voltage which may occur during fault conditions between the sound phases and ground may be calculated by the method of symmetrical components ("Symmetrical Components" by Wagner and Evans, McGraw-Hill Book Company). Under certain conditions, a two line-to-ground fault may be slightly more severe than a single line-to-ground fault.

Arresters of reduced voltage rating should not be applied except where the neutral is "effectively grounded" and the following conditions are met:

(*a*). The neutral of that portion of the system must be grounded at all times and under all operating conditions.

(*b*). The ratio of zero sequence reactance (including neutral reactance) to positive sequence reactance or negative sequence reactance X_0/X_1 or X_0/X_2 must be equal to two or less under the most severe fault conditions. Due consideration must be given to the circuit impedance as affected by sequential operation of circuit breakers.

It is recommended that the arrester voltage rating be at least ten per cent above the calculated maximum sound phase voltage to ground.

As a rough rule of thumb, in many cases, it will be found that:

1. If $X_0/X_1 = 2$ or less, an 80 per cent arrester may be used.

2. If $X_0/X_1 = 1$ or less, a 70 per cent arrester may be used.

These latter percentages should be applied to the *maximum* root-mean-square line-to-line voltage, which may exist under the most unfavorable operating condition, in determining the allowable arrester rating.

Connections of Lightning Protective Equipment on Distribution Circuits

The problem of protecting transformers against lightning is essentially a question of definitely limiting the surge voltage stress on the transformer insulation to values that it can withstand by the proper use of arresters or gaps, while coincidently providing a suitable path to ground for the surge.

Conventional practice provides a more or less suitable ground path for the surge by the use of lightning arresters or gaps connected between line and ground, but does not provide for the coincident necessity of definitely limiting the voltages that can appear across the transformer insulation during the surge discharge, except in the limiting case of negligible arrester ground resistance. As a consequence, primary to secondary flashovers frequently occur, resulting at least in blown transformer fuses with attendant service interruptions, if not in equipment failure, etc.

By providing suitable "interconnection" between arresters, secondaries, and tanks, the surge potential across the transformer insulation may be limited to the voltage drop across the terminals of the protective devices themselves which, in the event the latter are suitably chosen, will eliminate the great majority of the transformer service outages otherwise experienced. The benefits to be derived from interconnection are not limited to single-phase installations, but may be extended to include the customary polyphase installations as well.

It is not essential to permanently ground the transformer tank, from the standpoint of protecting the transformer itself. While interconnection eliminates the arrester ground resistance as a factor in the protection of the transformer itself, the necessity of providing a low resistance path to ground in order to finally dispose of the surge is just as important as ever.

There are various ways of connecting arresters and gaps between distribution transformer leads, the tank and ground. Also, different nomenclature has been used to describe these various connections. In order to avoid lengthy descriptions or drawings every time a certain connection scheme is mentioned, it is very desirable to adopt a uniform system of titles.

Figure 3 shows the more common connections used for protecting distribution transformers. The numerous schemes of connections have been grouped into three general classes and each class subdivided to cover the more detailed connections. This method of identification makes it possible to describe the scheme of connections used by simply stating whether a "non," "solid," or "gapped" interconnection is used and whether the transformer tank is isolated, grounded, or connected to ground through a gap.

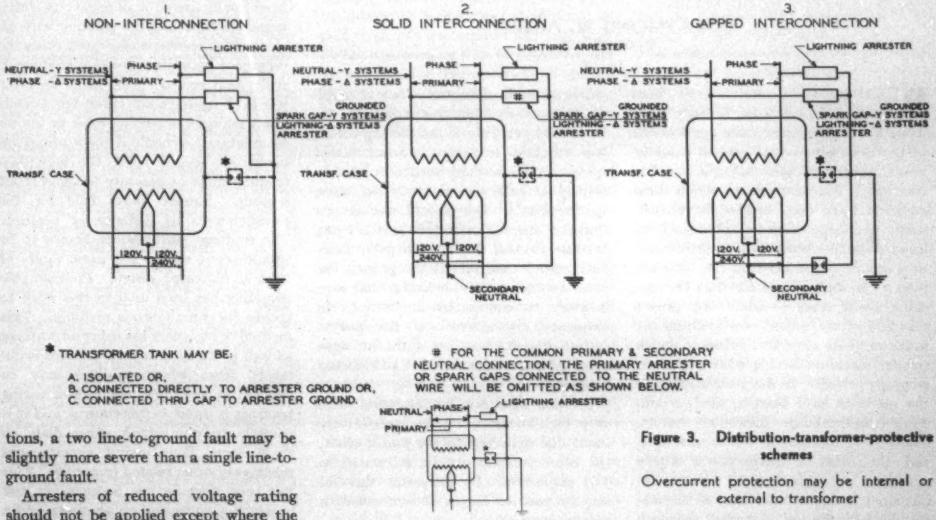

Figure 3. Distribution-transformer-protective schemes

Overcurrent protection may be internal or external to transformer

An Application of Deceleration Test Methods to the Determination of Induction-Motor Performance

By RAYMOND W. AGER
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RETARDATION tests have been used by industry for a long time. They have found their main applications in the determination of certain machine losses, usually friction and windage and core loss. The machines to which these methods have been applied have ordinarily had large mass and low rotational losses with the result that a considerable time would elapse between the time the power was shut off and the time the machine would come to rest. By proper selection of equipment and analysis the same methods may be applied to much smaller machines having relatively short stopping periods. In the present instance the methods have been applied to two double squirrel-cage induction motors, one a $7^1/_2$-horsepower 6-pole machine, and the other a 5-horsepower 4-pole machine. In each case the inertia was increased to about twice that of the motor alone by the use of a small flywheel. A similar analysis has been applied to acceleration tests on these two motors in which the motors were started at reduced voltage. By combining the acceleration tests with the decleration tests the speed-torque curves of the motors have been obtained. It is hoped that the discussion of the difficulties and the results of these tests will help to indicate the value and limitations of the methods as applied to similar determinations in this and other fields.

Quantities Involved and Their Measurement

There are five quantities involved in deceleration tests. These are inertia, time, position, velocity, and acceleration.

Inertia may be determined by calculation or test with the required accuracy. Its determination is not considered a part of this paper.

Time may be measured with extremely high accuracy. In the measurement of very short periods of time, however, a high-grade stop watch is almost useless since the registration does not go below one-fifth second. The synchronous clock will give indications to as fine a subdivision as desired but this indication can be relied upon only if the driving source has constant frequency. Some power systems are operated with a frequency control of sufficient accuracy for these measurements. One should not assume that the power frequency is constant just because electric clocks keep good time. Satisfactory time service for general use does not necessarily indicate that momentary or continuous fluctuations in frequency are absent. If the power-system frequency is not constant some other driving source for the clock should be used.

Position also can be measured with very high accuracy. Using a relatively small dial attached to the motor shaft, the rotor position can be estimated to 0.01 revolution. By increasing the dial size the position can be determined with greater accuracy.

Velocity is a derived quantity and cannot be measured directly with the accuracy with which one can measure fundamental quantities. Tachometers, whether electrical or mechanical, are subject to errors several times those which may exist in the measurement of time or position. The velocity may be determined more accurately from a properly taken distance-time curve than by direct measurement using tachometers. Another difficulty encountered in the use of tachometers is the load which the instrument places upon the machine being tested. If the machine being tested is small, the instrument may represent a burden which will mask the effects it is desired to measure.

Acceleration is a derived quantity of the second order. Satisfactory instruments for the measurement of accelerations as small as those found in deceleration tests are not available. The determination of acceleration must therefore be based upon calculations involving the velocity, which for best results must in turn be based upon the distance-time curve.

Since so much depends upon the distance-time curve, very high accuracy is required in its determination. It has been found that it is necessary to determine the time and the position with an error not exceeding about 0.002 times the difference between successive readings if truly good results are desired. In other words, if readings are taken ten seconds apart the time of reading must be known to about 0.02 second. If the readings are taken one second apart the individual readings must be accurate to about 0.002 seconds. Similar limits hold for the measurements of distance or position. The readings must also be known to be simultaneous within the same limits of time as indicated above. Photographic recording has been used in this work to obtain the simultaneous readings. This method of recording has other advantages as well in that a permanent record is obtained from which readings may be checked at any time, the rate of taking readings is under better control, and it is possible to photograph other dials on these same films giving simultaneous readings of other related quantities. This has been done in one acceleration test in which a voltmeter, an ammeter, and a polyphase wattmeter were photographed along with the time and displacement dials and their readings used to get the electrical characteristics of the motor.

Apparatus

The timing device was a synchronous clock, made for checking relay settings, etc. It was of the continuously rotating type and did not have the intermittent motion of the cycle counter. The clock had two hands, one of which made one revolution per second, and the other made one revolution in ten seconds, when supplied with 110-volt 60-cycle alternating current. The dial was calibrated with 100 divisions and time could be estimated to 0.001 second.

The position indicator was a watthour meter register which had the units dial directly coupled to the motor shaft. The coupling was by means of a tightly wound piano-wire flexible shaft slipped over a pin set in the center of the motor shaft on one end, and over the shaft of the units dial of the register on the other end. With the two shafts in line the hand appeared to follow the shaft movement accurately.

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The rotor position was estimated to 0.01 revolution.

The photographic equipment consisted of a candid camera clamped into position and accurately focused on the dials. The camera had a focal-plane shutter which was wound and tripped by hand. The camera had a maximum capacity of about 40 pictures at one loading. This number of pictures was adequate for most tests, although a slightly larger number could have been used to advantage at times. The marked shutter speeds ranged up to $^1/_{500}$ second but the actual exposure was found to be about twice this. Shorter times of exposure would have resulted in better images of the faster moving pointers, but the values obtained by estimating the position of the centers of the blurs caused by the moving pointers seem to have all the accuracy required. A distance of 30 inches between the camera and the dials was found to be satisfactory using the two-inch-focal-length lens.

The dials were illuminated by "photoflood" lamps. The lens was stopped down so that the resulting negatives would be much thinner than would be used for the more normal photographic work since it was found to be easier to read these thinner negatives. The readings were taken from the films using a pocket magnifying glass of about six power.

Standard portable-type voltmeters, ammeters, and wattmeters were used in the acceleration test in order to get the complete electrical characteristics. Figure 1 shows these instruments, the synchronous clock, and the position-indicator dial as they were grouped around the motor in the acceleration test.

Calculations

Because of the high accuracy of the data taken from the films, the velocities may be calculated from the differences between successive readings. That is, if the difference in distance (revolutions) as read from two successive films is divided by the difference in time as read from the same films, the average velocity during the interval is obtained. This calculation is indicated in table I, which lists the readings for the acceleration test of the $7^1/_2$-horsepower motor. The first and second columns contain the distance and time readings as they were taken from the films. The third and fourth columns show the differences referred to above, while the fifth column lists the quotient of these differences or the average velocities during the intervals. If each interval is of short enough duration so that the change in velocity is small during that interval, this average velocity may be considered as the true velocity at the time corresponding to the middle of the interval. How close this will be to the truth will depend upon the curve to which the calculations are applied. No approximations are involved if the velocity is a straight-line function of the time. The times corresponding to the velocities listed in the fifth column of table I are shown in the sixth column. However, if one is interested in the velocity-distance curve, the average velocity found above may be considered as the true value at the mid-distance of the interval. The accuracy of this approximation again depends upon the shape of the curve. In this case no approximation is involved if the velocity is a straight-line function of the distance. It is to be noted that the mid-distance and the mid-time points do not fall on the true curve of time and distance, but on straight lines joining successive points on the original curve.

It might seem that the velocity could be obtained by graphical means from the distance-time curve. It was not found to be feasible to do it this way, since the plotting of the curve could hardly be done with an accuracy comparable with that of the original data, unless the plot were made to an enormous scale. The process of calculating differences as outlined above results in accurate velocity data with a minimum amount of manipulation.

Now if a sufficient number of readings of distance and time have been obtained in the original data, a velocity-time curve or a velocity-distance curve may be derived having high enough accuracy for use in determining the acceleration. The slope of the velocity-time curve is equal to the acceleration. If one wishes to use the velocity-distance curve, he may find the acceleration by multiplying the velocity by the slope of this curve. This relationship may be shown as follows:

Since

$$v = ds/dt$$

and

$$a = dv/dt$$

$$\frac{a}{v} = \frac{dv}{dt} \times \frac{dt}{ds} = \frac{dv}{ds}$$

or

$$a = v\frac{dv}{ds}$$

It is to be noted that in either case the slope of a curve must be found. The accuracy with which one can determine the slope of an experimental curve depends upon the shape of the curve and the accuracy with which the location of the curve is known. The supposedly slight variations which would be expected in the judgment of curve location may produce relatively large changes in the slope of adjacent parts of the curve. The easiest and most accurate curve to draw, and the easiest one from which to determine slopes is that curve which approximates a straight line. Also, as inferred in the preceding paragraphs, this would be the one which would have the better approxi-

Table I

Revolutions	Time	Revolution Difference	Time Difference	Velocity	Time	Velocity Difference	Time Difference	Acceleration	Velocity
143.24	0.002								
		0.37	1.516	0.24	0.760				
143.61	1.518					1.15	1.787	0.644	0.84
		2.85	2.058	1.39	2.547				
146.46	3.576					1.14	1.780	0.638	1.96
		3.84	1.519	2.53	4.336				
150.30	5.095					0.89	1.477	0.602	2.97
		4.92	1.436	3.42	5.813				
155.22	6.531					0.87	1.470	0.592	3.85
		6.45	1.504	4.29	7.283				
161.67	8.035					0.82	1.513	0.542	4.70
		7.79	1.522	5.11	8.796				
169.46	9.557					0.86	1.538	0.560	5.54
		9.28	1.554	5.97	10.334				
178.74	11.111					0.87	1.637	0.531	6.41
		11.75	1.719	6.84	11.971				
190.49	12.830					0.91	1.677	0.542	7.30
		12.69	1.636	7.75	13.648				
203.18	14.466					0.83	1.665	0.498	8.17
		14.54	1.594	8.58	15.313				
217.72	16.160					0.83	1.689	0.491	9.00
		15.85	1.685	9.41	17.002				
233.57	17.845					0.84	1.708	0.492	9.83
		17.74	1.730	10.25	18.710				
251.31	19.575					0.82	1.723	0.476	10.66
		18.99	1.715	11.07	20.433				
270.30	21.290					0.79	1.697	0.466	11.47
		19.90	1.679	11.86	22.130				
290.20	22.969					0.72	1.631	0.441	12.22
		19.91	1.583	12.58	23.761				
310.11	24.552					0.71	1.650	0.430	12.94
		22.83	1.718	13.29	25.411				
332.94	26.270					0.77	1.784	0.431	13.67
		26.01	1.850	14.06	27.195				
358.95	28.120					0.64	1.692	0.378	14.38
		22.55	1.534	14.70	28.887				
381.50	29.654					0.60	1.575	0.381	15.00
		24.71	1.615	15.30	30.462				
406.21	31.269					0.65	1.595	0.407	15.62
		25.14	1.576	15.95	32.057				
431.35	32.845					0.57	1.658	0.344	16.23
		28.77	1.741	16.52	33.715				
460.12	34.586					0.60	1.741	0.344	16.82
		29.78	1.740	17.12	35.456				
489.90	36.326					0.56	1.683	0.333	17.40
		28.73	1.626	17.68	37.139				
518.63	37.952					0.44	1.619	0.272	17.90
		29.23	1.613	18.12	38.758				
547.86	39.565					0.43	1.652	0.260	18.34
		31.35	1.690	18.55	40.410				
579.21	41.255					0.41	1.705	0.240	18.75
		32.62	1.721	18.96	42.115				
611.83	42.976					0.16	1.752	0.091	19.04
		34.06	1.782	19.12	43.867				
645.89	44.758								

mations. One should therefore use the curve which more closely approximates a straight line.

These graphical methods for determining the acceleration from the velocity curves were used in the preparation of this article. As an extension of the method of taking differences to the determination of acceleration the last four columns of table I have been calculated, and further indicate the surprising accuracy of the data. The figures shown in the seventh and eighth columns are the velocity and time differences calculated from the values shown in the fifth and sixth columns. The quotients obtained by dividing these velocity differences by the corresponding time differences are the accelerations and are listed in the ninth column. The last column contains the velocities corresponding to the accelerations.

Accuracy of the Data

Although the foregoing shows very well the high accuracy which may be obtained, further improvement is possible so that some consideration of the sources of errors may be of value.

First consider the ability of the dials to follow time and position. The time dial should record time with the same accuracy as that with which the frequency is held constant at rated value. The tests which are reported were made on two large power systems. In one case the frequency fluctuations were of no consequence and the results are entirely reliable on this point. In the other case the frequency fluctuations were such that the results are somewhat in question. In this case the results of duplicate tests were similar but not identical. The distance or position dial should follow the motion of the rotor if the coupling is rigid. At first the coupling used was thought to be satisfactory as long as the shafts coupled by it were in line and the coupling was kept from vibrating. It is now believed that the greatest inaccuracies in this work originate here.

Since the camera had a focal-plane shutter the time of recording was not simultaneous over the entire picture. The progression of the exposure across the film should be the same in each picture and so should cause no errors due to the placing of the dials. However, an error will exist due to this sweeping action, since different portions of a single dial are photographed at slightly different times. Some irregularities in the curves have been traced to this source.

Procedure

From the above the general procedure should be obvious. Some of the details of procedure which must be watched will bear discussion. Bearing friction is a determining factor in these tests. Its value will vary with the bearing temperature, the load on the bearings, the axial position of the rotor, and the thickness of the oil film, as well as with the motor speed, the kind of oil used, and the general design.

Figure 1. General view of the instruments grouped for photographing in the acceleration test

Bearing temperature is very important. Changes in bearing temperature may affect the results to such an extent that any conclusions drawn from the tests may be entirely erroneous. This statement applies to ball-bearing machines as well as to those equipped with sleeve bearings. On successive tests on a new ball-bearing machine the bearing friction varied in the ratio of four to three although the time of running before the second test was only slightly greater than that before the first. The preferred procedure would be to run the motors to constant bearing temperatures before taking readings.

The addition of a flywheel to a motor may change the bearing friction and also the windage. In these tests all runs were made with identical flywheel loading and hence the effects of the flywheel should cancel out of the final result.

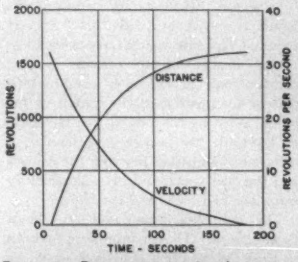

Figure 2. Distance-time and velocity-time curves for the deceleration test on the 7½-horsepower 6-pole motor

The axial position of the rotor may affect the bearing friction, or, by changing fan clearances, change the windage loss. This difficulty is not experienced in ball-bearing machines where end-play is restricted, but in sleeve-bearing machines there may be a tendency for the rotor to shift from its normal position during the test unless the shaft is carefully leveled and perhaps lightly restrained.

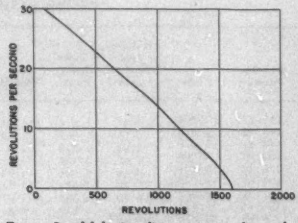

Figure 3. Velocity-distance curve from the test of figure 2

In deceleration tests the oil film should be properly maintained by the motion of the rotor. In acceleration tests, starting from rest, it may take several revolutions

before the oil film is built up to its proper value. It is therefore important to start acceleration tests after a period of running without allowing time for the rotor to settle and squeeze out the oil film.

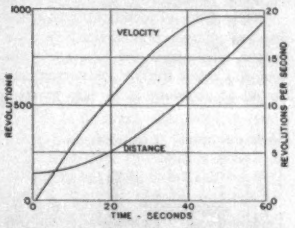

Figure 4. Distance-time and velocity-time curves from the acceleration test on the 7½-horsepower 6-pole motor

In trying to avoid the change in the oil film in the acceleration tests two methods were employed. The first was to run the machine and then allow it to coast to rest. The test was started within about one second of the time the motor stopped. The second method was to run the machine in the reverse direction and then to plug it on the line. Recording was started as the motor reversed. In analyzing the results of the tests made using the first method it was found that there was an apparent delay in the starting of the motor. In figure 4 this delay is indicated. In this test the power was applied at the time $t = 0.002$. This apparent delay is believed to be due to the inductance of the rotor circuit, which does not permit the field to build up instantaneously, and to transients which may exist at the closing of the line switch. The net result is that full torque is not available until some time after the closing of the switch and, therefore, the speed increases more slowly than it should at first. By plugging the motor on the line the time required for the building up of the field and the decay of the transients was provided before recording was started.

On deceleration tests the motor field tends to collapse on the removal of the applied voltage but is held trapped by the short-circuited rotor winding. Therefore, during the first few seconds the losses of the machine which must be supplied by the rotational energy include a stator core loss. Only after the rotor resistance has dissipated the energy of the field does this loss become zero and the friction and windage losses remain alone. A simple means of avoiding this core-loss error is to supply the motor with a higher frequency, running it at overspeeds so that the field will have become negligible by the time the speed has decreased to normal.

Since the camera used had a limited number of exposures, it was necessary to space these properly throughout the time of the test. In the deceleration tests the velocity-distance curves approximated straight lines and so were used in preference to the velocity-time curves. Since distance was used for the abscissa in these curves, a fairly uniform spacing of points on the curves was obtained by taking readings at approximately equal intervals

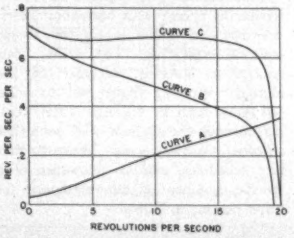

Figure 5. Acceleration and deceleration curves derived from the curves of figures 3 and 4

Curve *A*—Deceleration versus speed in the deceleration test

Curve *B*—Acceleration versus speed in the acceleration test

Curve *C*—Electrical torque versus speed

of distance. In the acceleration tests, however, the velocity-time curves were more nearly straight lines and were therefore used in determining acceleration. For these tests proper spacing of points was obtained by taking readings at approximately equal intervals of time.

Curves

Figure 2 shows the distance-time and the velocity-time curves of the 7½-horsepower 1,200-rpm 60-cycle motor in the deceleration test. The motor was run at overspeed by supplying power to its stator at about 100 cycles. In figure 3 the same data are used to plot the velocity-distance curve. It is believed that some of the waviness of the curve is due to fluctuations in the frequency of the supply used to drive the synchronous clock. Figure 4 shows the distance-time and the velocity-time curves of the same motor when accelerated from rest by applying three-phase 60-cycle power to the stator. The voltage was about 16 per cent of rated value. The power was applied at the time $t = 0.002$. The apparent delay in starting in this case amounts to about 0.5 seconds. It is probable that the curve should not plunge into the axis at this point but should contain a reverse bend which would bring it over through the origin. It is also probable that the transients causing this apparent delay have decreased the slope of the curve near the origin so that the torques calculated for the lower speeds are too low.

Curve *A* of figure 5 shows the deceleration as calculated from figure 3, curve *B* shows the acceleration as calculated from figure 4, and curve *C* shows the sum of the ordinates of *A* and *B* and gives the speed-torque curve of the motor. This

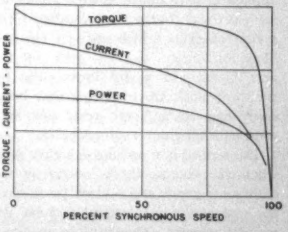

Figure 6. Complete starting characteristics of the 7½-horsepower 6-pole motor

speed-torque curve of the motor is redrawn in figure 6 in combination with curves showing current and power input. The inertia, spring constants, and damping of the instruments used to measure the current and power have undoubtedly affected the readings near zero speed

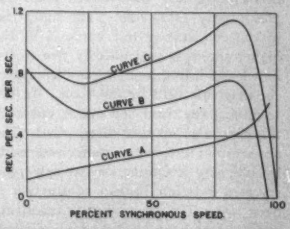

Figure 7. Deceleration, acceleration, and torque curves from the tests on the five-horsepower 4-pole motor

since power was applied at that time. A slight effect may also be present at the higher speeds but except near zero speed the pointer movements were so slow that errors due to this should be negligible.

In figure 7 are shown the curves obtained in tests on a five-horsepower 1,800-

A Variable-Register-Ratio Watt-Hour Meter

By G. R. SHUCK
MEMBER AIEE

AS is generally recognized, electrical energy is a commodity, the sale of which should be subject to the same economic laws that apply to other commodities. The two most important economic laws which regulate the sale price are (1) the law of diminishing costs, and (2) the law of supply and demand.

The first of these laws is partially applied in our present system for metering electrical energy, the so-called block system charging a high price for the first block of energy, a lower price for the next block, and a still lower price for the third block, the whole schedule being equivalent to a lower price per kilowatt-hour for greater consumption.

The second law justifies a higher price when the commodity is scarce or the demand is great, and a lower price when the commodity is plentiful and the demand the least. This law has an application in the 24-hour load cycle of an electric-utility company. The ever increasing peak load of the period between 4 p.m. and 9 p.m. indicates a greater demand and a limited supply, justifying an increased price. The period from 12 midnight to 5 a.m. indicates little demand and an unlimited supply, justifying a decreased price per kilowatt-hour.

Unfortunately, our present method of measuring energy with watt-hour meters does not and cannot supply this second law of economics. The utility rate makers do, however, recognize this law and are applying it in part to some schedules, such as domestic water heating, through the medium of off-peak time switches, carrier-current control, flat-rate schedules, and an allowance of a specific number of kilowatt-hours for water heating in billing.

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Although water heating is especially applicable to off-peak control, owing to the heat-storage capacity of water, other loads, both domestic and commercial, could in part be kept off-peak, particularly if there was some incentive for the consumer to do so.

The practice of cutting off water heating loads during peak hours is not altogether satisfactory and is not a logical long-run policy for the utility companies to adopt, because it is only partially effective and does not apply to all shiftable loads.

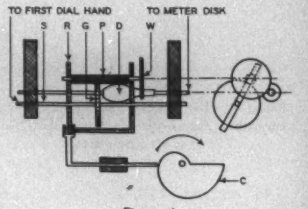

Figure 1

Rather than go to the expense of utilizing schemes for cutting loads off the peak, requiring additional wiring, meters, and timing devices, would it not be more logical to develop some metering system which will automatically take into account this second law of economics? These loads may be left on the system at all times, subject to a higher rate during the daily load cycle when energy is scarce and the demand great, and subject to a lesser rate when the energy is plentiful and the demand least. The consumer may himself apply automatic time switches on his load, or control them manually or not at all, as he chooses.

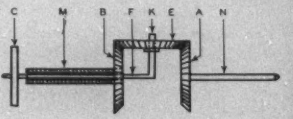

Figure 2

In order to investigate the possibility of applying the law of supply and demand in the metering of electrical energy, the writer, in the University of Washington laboratories, constructed a metering unit from a standard watt-hour meter, which will be called in this paper a variable-register-ratio watt-hour meter.

The variable register ratio is obtained by introducing in the registering train of gears, a drum, and wheel. The position

rpm 60-cycle motor. In this case only 60-cycle power was available and the deceleration test was started from approximately 1,800 rpm. The sharp rise in the deceleration test curve *A* at the higher speeds is undoubtedly due to the iron losses introduced by the trapping of the magnetic field by the rotor. In determining the combined curve, curve *C*, this sharp rise has been disregarded. The acceleration test on this motor was made by plugging it on the line at full-speed reversed rotation instead of starting it from rest. The errors due to transients at the start have thus been eliminated. For this motor dynamometer tests were available in which starting torque, pull-out torque, and the minimum torque between these two had been determined. The ratios of these torques as determined in these tests and as determined in the dynamometer tests checked within about two per cent. An agreement as close as this was somewhat unexpected considering some of the known errors and the widely different voltages used.

Conclusions

These tests would indicate that the method is quite usable and that the results should be quite satisfactory if the proper precautions are taken. The apparatus required and its costs are relatively small if the phenomena investigated are not of too high speed. With further refinements and the use of stroboscopic cameras, giving finer subdivisions of time and distance, higher-speed phenomena may be investigated, with, of course, an increase in the cost and the complexity of the apparatus.

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of the wheel with respect to the drum is changed during the day by means of a timing unit.

The shape of the variable-diameter drum should be such that the meter registers more slowly during off-peak hours. In general the shape of the drum should correspond to the daily load curve.

Figure 1 is a schematic drawing of that part of the registering train which has been altered. The drum D is mounted on one of the shafts of the registering train of a standard watt-hour meter. The wheel W and pinion P are mounted on a carriage rack R, the latter arranged to slide longitudinally as well as turn on shaft S. The gear G solid on shaft S meshes with the long pinion P with the carriage in any position. The motion is transmitted from the meter disk through drum D to wheel W, pinion P, gear G, to the first dial hand.

The rack R is moved to the left along shaft S by means of the cam C and a push rod, and returned by means of a spring when released by the cam. The forward motion takes place in a little less than 24 hours, the return motion in about five minutes, the complete cycle in exactly 24 hours.

The cam C is rotated at one revolution per day by means of a timing unit shown in figure 2. Gear B, mounted solid on the hollow shaft M, is driven by a synchronous clock at two revolutions per day. Gear A, mounted on shaft N, is driven in the same direction by an ordinary hand-wound clock at two revolutions per day. The gear E, meshing with both gears A and B, rotates on shaft K and revolves with shaft F, the latter passing through the hollow shaft M. The cam C, also shown as C in figure 1, is driven by shaft F. If either gear A or B rotates while the other is stationary, the shaft F is caused to rotate one revolution per day.

In operation, the synchronous-motor clock drives the shaft F and cam C, while the hand-wound clock and gear A are stationary. In the event of a power interruption, the synchronous-motor clock stops, and the hand-wound clock starts up and drives shaft F until the power again comes on and the synchronous motor resumes its duties. The hand-wound clock is designed to start or stop automatically by means of a very small electromagnet which controls the motion of the balance wheel of the clock.

In order to discuss the application of this metering system to a schedule, the 24-hour day may be divided into periods such as normal, off-peak, and peak periods. The normal periods may, for example, be assumed to be from 7:00 a.m. to 4:30 p.m., and from 6:30 p.m. to 11 p.m.; the peak period from 4:30 p.m. to 6:30 p.m.; and the off-peak period from 11 p.m. to 7 a.m.

The diameter of that part of the drum corresponding to the normal periods will be such as to cause the watt-hour meter to register true kilowatt-hours. The diameter of that part of the drum corresponding to the peak period will be greater, causing the meter to register more than

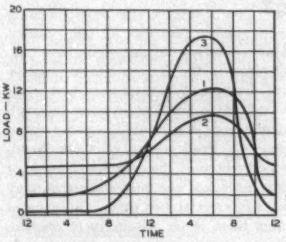

Figure 3. Customer-load curves

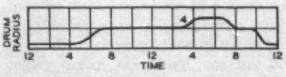

Figure 4. Variable-register-ratio drum radii

the true kilowatt-hours. The diameter of that part of the drum corresponding to the off-peak period will be such as to cause the meter to register less than the true kilowatt-hours.

Obviously any consumer cannot be expected to have a 100 per cent load factor. He is entitled to use a certain amount of energy during peak hours, and is also expected to use some energy during off-peak hours. The average consumer may be assumed to have a normal load curve, just as the power consumer is expected to maintain a normal power factor within reasonable limits. For purposes of discussion load curve 1 (figure 3) may be considered to be a normal load curve.

The peak and off-peak diameters of the drum may be so calculated that, during a 24-hour period, the variable-register-ratio watt-hour meter, equipped with this drum, will register the true kilowatt-hours of a normal load. That is, a consumer having a normal load curve would have the same kilowatt-hour registration during the month as he would have if his load were metered by a standard watt-hour meter. Curve 4 (figure 4) shows the shape of such a drum. Curve 5 (figure 5) shows the registration of the variable-register-ratio meter for load curve 1 (figure 3) indicating a total registration of 192 kilowatt-hours.

Assume that the consumer has a load curve 2 (figure 3) equal in kilowatt-hours to the normal load curve 1, but showing less peak and more off-peak load. The actual registration curve of the variable-register-ratio meter is shown in curve 6 (figure 5) giving a total daily registration of 172 kilowatt-hours.

Assume the consumer has a load curve 3 (figure 3) equal in kilowatt-hours to the normal load curve 1, but showing more peak load but less off-peak load. The actual registration curve of the variable-register-ratio watt-hour meter is shown in curve 7 (figure 5) giving a total registration of 218.

These curves show that a given number of kilowatt-hours will give different registration, depending on *when* the energy was used.

In some two-rate schedules involving large blocks of power the maximum demand is determined by a graphic recording wattmeter, and the charge per kilowatt of maximum demand varies, depending on when the maximum demand occurred, whether off-peak or on-peak. In two-rate schedules involving small blocks of power the indicating maximum-demand register is used. This method gives no indication of the time of day the maximum demand occurred. If a maximum-demand attachment were installed on the variable-register-ratio

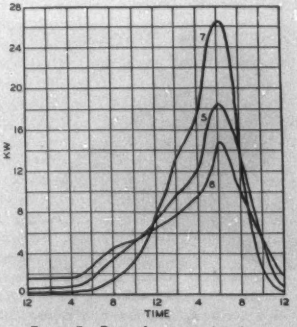

Figure 5. Rate of meter registration

watt-hour meter, it would automatically register a higher or lower indication, depending on the time of day the maximum demand occurred.

The variable-register-ratio watt-hour meter may be used in a different way by

having two registers, one a standard dial, the other a variable-register-ratio dial. The standard dial registers the true kilowatt-hours as any other standard meter. The variable-register-ratio dial gives the modified registration as already explained. The ratio between these two readings gives a modifying factor K which may be used in billing the true kilowatt-hours.

Assume the consumer has the normal load curve 1 (figure 3). Both dials will indicate the same, namely 192, and the factor K will be $^{192}/_{192} = 1$. Assume the consumer has load curve 2. The standard dial will again register 192, but the variable-register-ratio dial will register 172. The factor K will be $^{172}/_{192} = 0.895$. Assume the consumer has load curve 3. The standard dial will register 192. The variable-register-ratio dial will register 218. The factor K will be $^{218}/_{192} = 1.135$. The factor K obtained each month is a measure of *when* the energy was used and may be used as a modifying factor in billing the true kilowatt-hours.

The meter constructed in our laboratories (figure 6) consisted of parts of other meters assembled together into a working unit to test the general method, and is essentially a crude instrument compared to one which would be designed and constructed by a manufacturing company. However, some information was obtained which leads to the following conclusions.

1. A variable-register-ratio watt-hour meter can be constructed of sufficient accuracy and low cost to compare favorably with the present methods of controlling off-peak loads, and at the same time to have more universal application.

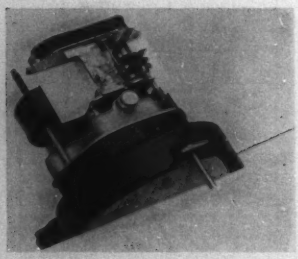

Figure 6

2. Tests were conducted to show the accuracy of transmission through a drum and wheel. The ratio between the frictional torque at the wheel and drum, and the torque required to drive the registering train was found to be three to one, showing a sufficient factor of safety in regard to the wheel slipping on the drum. A proper design and choice of material could, no doubt, increase this factor many fold.

3. The timing device should consist of a synchronous-clock motor with an auxiliary hand-wound or electric-wound clock designed to run not more than 24 hours, since power interruptions sum up to be far less than 24 hours during one month. It was found by test that the smallest type of synchronous motor produced 100 times as much torque as was necessary to rotate the cam.

4. The design of the unit should be such that the drum of the variable-register-ratio dial can be removed and another inserted without dissembling the registering train, to conform to any desired rate schedule. If it is desirable to convert the variable-register-ratio meter into a standard watt-hour meter it is only necessary to slip in a cylinder of proper diameter, or to replace the entire register with a standard registering dial.

5. In view of the probable objection on the part of the rate commissions that the variable-register-ratio meter does not actually register kilowatt-hours at all times, the second method of the two outlined in this paper would be more acceptable, the meter being used to obtain a monthly modifying billing factor.

Trends in the Design and Arrangement of Electrical Equipment in Hydraulic Power Plants

By C. C. WHELCHEL
MEMBER AIEE

DURING the last ten years there has been a considerable development of water power resources in this country. Many different organizations have participated in the design of these projects, and many contributions have been made to reduce the first cost, improve the over-all efficiency, and reduce the cost of operation. A brief review of those trends which represent the greatest changes, or have provoked the most discussion, may be of interest at this time. On many of them there is no unanimity of opinion. The reader may disagree with some, he may even question whether others represent general trends at all; nevertheless, the writer will try to give them without either commendation or condemnation, and he would not be entirely candid if he did not say that some looked rather foolish to him at first. It should be emphasized that this paper will discuss only those features which have been changing, or have provoked discussion; many things which are of much greater importance to the station may therefore be mentioned only briefly, if at all.

Powerhouse

A number of semioutdoor type of generating stations have been built in which the conventional powerhouse superstructure was omitted. In this design the generator-room floor becomes the station roof, the generators being protected by a concrete or metal housing. An outdoor gantry crane is usually provided for removing the waterwheel and generator parts to one end of the station, where they may be lowered through a hatch to the inside repair bay below. The layout of the generating units and their auxiliaries is arranged so that practically all operation in connection with the equipment will be below the generator deck, where complete protection is obtained. There is a considerable difference of opinion as to the true over-all saving with this type of plant, particularly where the extra cost of installation and maintenance is taken into account. If experience demonstrates the absence of operating and maintenance difficulties, they may be more generally adopted in the future.

In the past, it has been the general practice to locate the generators in the powerhouse above the maximum expected flood waters, and in many cases this has resulted in an expensive structural design, because of the distance between the waterwheel and generators. In several

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recent projects, it was found that the most economical arrangement was to place the generators as close to the waterwheels as ordinary considerations would allow, and protect them from flood waters by building a waterproof powerhouse without windows. This type of station naturally results in an indoor design, since the walls are essential for flood protection, and only a roof is necessary to enclose it.

Generators

Further economy in power-plant design has been achieved by an increase in the size of the generators and waterwheels over those which would have been considered practicable a few years ago. Operating efficiency has been improved by the increased use of the adjustable-blade turbine for low-head developments. Although these trends principally represent an advancement in the design of hydraulic machinery, they, of course, affect directly the generating equipment. The largest unit in physical size at a particular speed which it is possible to build economically at the present time has not been reached, but it has been closely approached. The limiting factor in waterwheel-generator design is usually the mechanical stresses at runaway speed.

There has been very little change in the structural design of waterwheel generators in the last few years. Fabricated construction continues to be widely used. Partly because of the accuracy with which the strength of fabricated rotors can be predetermined, and partly because of the expense of building up and tearing down again to meet shipping limitations, particularly on the larger size units, overspeed tests are seldom made at the factory.

Overhung or umbrella type of generators with one guide bearing have been installed in a number of stations. Such generators show a slight saving in first cost over the conventional two-guide bearing type. There is, however, an upper limit in speed and physical size beyond which it is not practical to go. Owing to the lack of an upper-guide bearing on the generator, these machines are tested with the waterwheel attached. The design therefore is more difficult to test and does not lend itself readily to the investigation of vibration and other possible troubles.

The highest voltage waterwheel generator built so far in this country is 16.5 kv. Studies have been made on the larger units for voltages of 23 and 34.5 kv with the result that a more conservative and economical design was obtained with a generator voltage of 16.5 kv or less, and a step-up autotransformer. This combination is as efficient as a generator wound for 23 or 34.5 kv.

The advancement in the knowledge and appreciation of system stability has generally resulted in a more careful study and selection of those generator characteristics which affect stability.

A fuller understanding of the general operating advantages of amortisseur windings in waterwheel generators has resulted in their incorporation in a number of units. The principal advantages are: the reduction of overvoltages in the stator winding resulting from unbalanced faults on the generator, particularly on unloaded machines coupled to capacitances such as transmission lines; the effective reduction in oscillations of generator-output kilowatts occasionally experienced on machines which are connected to their loads through high resistance circuits; and a minor aid in system stability by reducing the magnitude of the rotor oscillations.

Experience has shown that even though water-power developments are usually located in rural districts, the air is not free from impurities which lodge in the generator and interfere with the effective cooling of the machine. For this and other reasons the closed ventilating system, using surface air coolers, has been adopted for most of the recent generators above 5,000 kva. In addition to the longer expected insulation life, the closed system reduces station noise and provides increased fire protection. In some installations it permitted a more economical powerhouse, since provisions for large air intake and discharge openings in the building were not required.

On very large generators, where the stacked height is sufficient, the cooler sections have generally been arranged vertically around the periphery of the generators. On the comparatively small machines, where the stacked height is so short that a vertical arrangement around the periphery would be expensive, the sections have been located parallel to the floor, and on the side of the unit for vertical machines, and underneath for horizontal units.

Of the hydraulic generators which have been provided with surface air coolers, less than half are arranged to discharge air to heat the power station. The trend is in the direction of permanently closing the generators, and deriving station heat from some other source, because obviously any departure from the closed system reduces the effectiveness of that system.

Although generator fires are rarer now than ever before, carbon-dioxide fire protection has been provided on many of the larger generators, because of its effectiveness on the closed ventilating system as compared to the open system.

In the larger-size generators which require extensive disassembly for shipment, it has become the general practice to make the electrical tests as well as overspeed tests after installation.

Excitation Schemes

The excitation scheme, used almost exclusively in the last few years on generators rated 3,750 kva and above, employs direct-connected main and pilot exciters, and a high-speed individual rheostatic voltage regulator operating in the main exciter field. A main a-c generator-field rheostat is not required, and in a number of instances the armature of the main exciter is permanently connected to the generator field without a field switch. No provision is made for paralleling exciters.

The operating simplicity of the direct-connected exciters has a very strong appeal. This system generally has the advantage of lower cost, considering in one case a shaft alternator and a motor generator set, and in the other case a direct-connected exciter plus a small step-down power transformer to serve the machine auxiliaries otherwise served by the shaft alternator. Beyond this difference in price is the additional switching equipment, such as circuit breakers and switchgear panels, not to mention increased wiring and cable connections.

Because of the low outage record of direct-connected exciters, the complications introduced by trying to provide spare excitation in what is otherwise a unit system, and a station design which contemplates the outage of a complete generating unit without adversely affecting operation, the spare motor-generator exciter set has been omitted in a number of stations.

In many stations, advantage has been taken of the possibility of allowing considerable variation in generator voltage in order to obtain better system-voltage regulation. In such stations line-drop compensation has usually been incorporated in the generator voltage regulators. In a properly co-ordinated generator voltage regulating system there is no conflict between line-drop and cross-current compensation.

Governor Flyball Drive

One of the early steps taken to free the governor flyball drive from the physical

limitations of a belt was to provide a flyball motor and drive it from the main generator terminals through small transformers. This type of drive was found to be satisfactory in most instances, although it has the disadvantage of tending to cause the governor to follow system frequency rather than generator frequency during those rare cases when the main unit twists out of step with the system due to instability.

Although this condition has occurred very rarely in practice, the desirability of eliminating it was early recognized. The next source of power used was obtained from slip rings on the pilot exciter. Where steps were taken to obtain proper co-ordination in design between the governor motor and pilot exciter, this scheme has operated satisfactorily. Where this was not done, trouble has been experienced in some installations due to a very sensitive governor head along with slight phase-shifting of the pilot exciter flux with respect to the shaft of the main unit, with the result that the governor did not see true shaft speed at all times.

A permanent magnet generator directly mounted on each unit is the latest source of power supply for governor flyball motors, and is the system which has generally been used in the last few years.

Circuit Arrangements

Hydroelectric-generating-station switchgear shows a decided tendency toward simpler circuit layouts including the elimination of generator oil circuit breakers and low-voltage busses, resulting in a considerable saving in cost, as well as a greatly simplified station design.

The so-called unit system has been widely adopted. The simplest case with this scheme is to have one generator connected to its own individual transformer bank. In the earlier installations an oil circuit breaker was installed between the generator and transformer primarily for synchronizing purposes. The present oil circuit breakers of all voltages have closing speeds sufficient for synchronizing on the high-voltage bus, so that in the more recent installations the breaker between the generator and the transformer has been omitted.

Some stations have used a modification of the unit scheme in which two generators are connected to one transformer bank, each generator having its own low-voltage breaker in order to be able to synchronize or remove one generator from service without affecting the other.

Many operating engineers have concluded that the unit scheme with its omission of the low-voltage bus represents practically no sacrifice in over-all station reliability or flexibility. Although this scheme is open to the criticism that, if a generator fails and at the same time a transformer normally connected to another generator also fails, the output of the two machines is lost, operating records show that such a contingency is very unlikely to occur. Furthermore, few plants are designed on the basis of two simultaneous failures, since their cost would be prohibitive.

Switchgear Equipment

Although the simpler circuit layouts now so prevalent in hydro stations have appreciably reduced the number of low-voltage oil circuit breakers, nevertheless many stations still require large-interrupting-capacity breakers in addition to the smaller ones for controlling station-service power.

In many of the more recent projects, these breakers, their disconnecting switches, busses, etc., are enclosed in complete factory-built metal structures. Metal-enclosed busses from the generator terminals to the power transformers are also being used.

The increasing use of metal-enclosed gear is attributed to the more general appreciation of its economy and safety features. By using this equipment, station planning has been simplified by eliminating the time and expense in detail designing and co-ordination which is required where cell-mounted equipment is used. Savings in building cost have been realized in many instances, because this type of gear saved floor-space and headroom. As a rule, metal-enclosed gear has been found to cost less installed than other types in which equal precautions have been taken to preserve service continuity.

Many refinements in oil-circuit-breaker design have been made in the last few years. More effective means for controlling the interruption of the arc has permitted smaller oil circuit breakers for the same voltage, current, and interrupting rating. Faster operating mechanisms are now being used to speed up the tripping and closing times, thereby reducing system disturbances. In the high-voltage field, oil circuit breakers rated 287 kv and, having a clearing time of three cycles, have been installed. Inasmuch as these breakers were of very low oil content, they evidenced the trend toward low-oil-content breakers.

Metal-enclosed air circuit breakers or contactors are extensively used for controlling station service power at 550 volts or less. This equipment permits a still further reduction in fire hazard and its compact construction results in a saving in space and installation expense.

Control Boards

The tendency is toward the so-called duplex board with control, indicating instruments, etc., on the front panels, and relays, meters, test blocks, and similar equipment on the back panels. In some of the larger power plants, supervisory type of control has been mounted on duplex panels. Such control eliminates some of the wiring complexities, permits a smaller switchboard control room, and makes it possible for the operator to follow station conditions more readily since the essential information is concentrated in a relatively small space.

The advantages of supervisory control are secured by locating cubicles adjacent to the generators with which they are associated. The duplex switchboard located in the main control room has supervisory control over these cubicles. Only those indications and controls which are required for station operation are provided on the duplex board, thereby reducing the number of instruments and devices, and the amount of interconnecting control cable. A signal system is used to indicate abnormal operating conditions, which in some instances may require the attention and assistance of a generator floor man. In an emergency the generator floor man can take over the operation of the unit at the generator cubicle.

Automatic synchronizing equipment has been provided to a greater extent than in the past, because the operation is accomplished smoothly and without the switchboard operator's neglecting other important duties at that time.

Station-Service Power

The supply of station-service power, like excitation schemes, has run a varied and interesting course. Like excitation with which it has at one time or another been closely associated, the trend has been toward greater simplicity, influenced perhaps as much as anything by a careful re-examination of the basic service requirements of the individual devices that make up the station-service load. After doing the same thing the same way for a few years, additional experience gained in that time frequently demonstrates that the requirements are not so severe as they had been assumed, or else the improvement in apparatus permits a simpler

solution. Such has been the case with station-service power.

With the use of direct-connected exciters instead of motor-generator exciter sets, the principal reason for the shaft auxiliary generator was eliminated. The simplest and most economical system for obtaining station-service power, which at the same time possesses a high degree of flexibility, has been obtained by connecting a small step-down transformer to the generator leads, either directly or through a disconnecting switch. This system has been widely adopted in the last few years, particularly in stations without a low-voltage bus.

With this scheme the auxiliaries intimately related with each generating unit are fed from the transformer connected to the terminals of that generator. This transformer usually supplies a low-voltage bus from which emanate the leads to the various unit auxiliaries, such as governor oil-pump motor. To give duplicate service to this bus for emergency or starting up the station, power is fed from an adjacent bus, a house generator, or a high-voltage step-down station-service transformer bank.

Present indications are that the unit station-service-power scheme may be used in the future, even in stations with a low-voltage bus, since it permits the elimination of an expensive high-interrupting-capacity switch position.

Grounding and Protective Equipment for Generators and Transformers

It is difficult to discern any particular trend in generator-neutral grounding and relay protection on units connected to low-voltage busses from which feeders emanate. Such generators are either solidly grounded or else grounded through a neutral impedor. The limits are, on the one hand, a sufficiently low value to stabilize the system neutral, and on the other, high enough to minimize damage resulting from faults.

In stations employing the unit system, where each generator is directly connected to the delta side of its own step-up transformer, the relaying and grounding trends have been interesting. In many stations, the generator neutral is solidly grounded. This permits the generator differential relay to protect the maximum amount of the generator winding on phase-to-ground faults, but on the other hand grounding the neutral solidly has the disadvantage of permitting the maximum amount of fault current.

Damage resulting from a fault, however, depends on duration as well as magnitude. In following the approach of reducing fault duration, high-speed balanced-beam differential relays operating in one or two cycles have been used in a number of stations, instead of induction-type relays having six- to eight-cycle operating times. This reduces the overall fault-clearing time from approximately 14 cycles to 9 cycles where the generator-neutral breakers are used to unground the machine.

Because of the increased cost of the very special current transformers now required to provide high-speed generator differential relaying and the comparatively small gain in time in extinguishing the arc, there is a trend back to induction-type relays. This trend is perhaps further influenced by the feeling that if damage from line to ground faults is the principal reason why generator differential relays have been speeded up, then the more direct attack on the problem is to insert an appreciable amount of resistance in the generator neutral, or unground it entirely, as has been done in some stations. In the latter case, a ground detector which signals the station operator, but does not trip the unit, is usually employed. This permits temporary operation until a shutdown can be conveniently arranged.

There has been some interest in high-speed transformer differential relaying, but in the case of power-transformer protection, the problem is more difficult than in the case of generator-differential protection, for not only must instrument transformers be matched with bushing transformers, but even more important, provision must be made to prevent false tripping during magnetizing inrush periods. Despite these difficulties installations of high-speed transformer differential relays have been operating quite satisfactorily. The choice between high-speed and induction-type percentage differential relays is largely dictated by stability considerations.

There has been a trend toward the increased use of bus differential protection where there were large concentrations of power because the preservation of service continuity requires the speedy clearing of the large resulting fault currents. From the protective standpoint the presence of large fault currents causes current-transformer saturation that tends to operate the differential relays during faults external to the bus. The relay current in the case of an external fault differs from that arising from a bus fault, in that it has a large harmonic content. The recognition of this difference has led to the development of a harmonic-restrained high-speed bus differential relay, which will undoubtedly find increasing use in the future.

In the past, generators feeding through step-up transformers were generally believed to be immune to lightning due to the fact that the transformer bank would act as a buffer against incoming waves. It is now known that this is not entirely true, and consequently generator lightning-protective equipment is commonly installed. Experience has indicated that a relatively small investment in properly selected equipment will provide a degree of protection that will result in a material reduction of the possible lightning stresses imposed on rotating machines and contribute to an appreciably increased security against faults due to lightning-impulse voltages.

Outdoor Substations

The arrangement of the high-voltage equipment at a hydro station is largely influenced by the topography of the site and the location of the powerhouse. In those projects where the outdoor switchyard is separated more than a few hundred feet, the general practice has been to locate the step-up transformers adjacent to the powerhouse, and conduct the power to the outdoor switchyard by means of overhead high-voltage lines.

Outdoor substations at 66 kv and above are commonly shielded by overhead ground wires which extend out over each line for at least half a mile. The use of overhead ground wires has increased the height of the outdoor structure somewhat and requires slightly heavier steel to carry the additional load, not only in dead weight, but also to carry the take-offs on the outgoing lines. These items represent only a small addition to the total cost of the station.

Shielding of outdoor substations practically eliminates the possibility of direct strokes nearer than half a mile from the substation, thereby limiting the incoming surges to a value that a lightning arrester can handle. In spite of a considerable discussion during the past few years of the real merits of plain gaps versus lightning arresters for apparatus protection, arresters continue to be in very general use. This is for the reason that gap settings which give a degree of protection comparable to that of lightning arresters result in more dynamic flashovers than can ordinarily be tolerated.

Power Transformers

The trend in the design of power transformers continues to be in the direction of

improvement in the dielectric strength and refinements in mechanical construction. Much attention has been given in the last few years to the study of insulation co-ordination, resulting in improved insulation strength to resist lightning, and the proper distribution of impulse stresses throughout the transformer winding obtained, for example, by the use of shielding.

There is a trend in the larger size transformers toward the use of the gas-sealed unit, wherein the space between the oil and the cover is filled with dry nitrogen gas. In addition to providing a seal against the entrance of oxygen, moisture, dust, etc., some operators feel that the fire hazard is less, because the oil level is below the transformer cover. The outstanding contribution from the design standpoint toward minimizing the fire hazard in power transformers, however, results from the use of a noninflammable liquid instead of transil oil. Indications point toward an increased use of such transformers in the future.

The general tendency in this country has been to install single-phase transformers to form three-phase banks, even where three-phase transformers were practicable from a physical standpoint. A re-examination of this problem from the standpoint of outage, handling, and reliability, indicates an increased interest in three-phase units.

Strange as it may at first seem, several recent large hydro stations have installed self- or forced-air-cooled transformers. The elimination of the cooling water system has influenced their selection to some extent. Another consideration was the ability to obtain outputs above the self-cooled rating with forced air. The latter is directly attributable to the generator rating and temperature rise. Most generators rated 11 kv and above use class *B* insulation, with class *A* temperature rise. Operating experience with such a design indicates a longer life and one capable of carrying some emergency overload. This requirement may arise under the most favorable hydraulic conditions, since at that time the capacity of the waterwheel may be in excess of the normal generator rating. The air-pressure cooling equipment on the power transformer provides an economical means of obtaining transformer capacity to match the maximum generator output.

Step-up transformer high-voltage-neutral grounding shows a trend away from solidly grounding in the direction of grounding through an impedance, and in a recent installation at 220 kv this impedance was a Petersen coil. The experiences with these coils in this country in the last few years indicates a more general acceptance of this device for improving system performance.

Because of the desire to obtain noninflammability of the liquid, as well as to eliminate explosions of the arc-formed gases, there is an increased use of noninflammable synthetic insulating oil in station-service transformers, particularly those installed in the powerhouse.

Summary

From the foregoing discussion, it has been seen that the outstanding trends in the design and arrangement of electrical equipment in hydraulic power plants, with but a few exceptions, are toward greater simplification, reliability, and lower first cost. Inasmuch as fixed charges constitute the major portion of the cost of hydro power, a reduction in first cost affords the principal means for securing a reduction in the cost of water power.

Discussion

J. H. Foote (The Commonwealth and Southern Corporation, Jackson, Mich.): This paper covers the subject in a comprehensive manner and gives a good general picture of some of the developments in the design of hydraulic plants and the equipment which goes into them. Many of the types of design and the features outlined in this paper have been used successfully by our associated companies for a number of years.

Powerhouse

In 1925, we designed and built a hydraulic power plant, utilizing the semioutdoor type of construction, with two 1,060-kva units. This plant is of the automatic variety and this type of construction has proved satisfactory from an operating standpoint.

Generators

We have also utilized the enclosed type of air-cooling system for the generators of one of our newer large hydraulic power plants with satisfactory results.

It might be pointed out that the testing of umbrella-type generators in the field, with the waterwheel attached, may be of small consequence if both units are of the same manufacture, but if different manufactures are involved, it may be very important to be able to test the units individually.

Excitation Schemes

Direct-connected main and pilot exciters have been used on our hydrogenerators since 1924 with satisfactory results. In fact, direct-connected exciters have been employed without spare exciters or excitation busses since 1905 with success. No exciter failures have been experienced, and the practice of not providing spare sources of excitation has not caused us any difficulty. It is felt that the chief advantage of using the pilot exciter is that greater stability of the excitation system is obtained.

It has been noted with interest that in certain cases field switches have been omitted. We have successfully operated four generators so connected since 1922. In many of our generator-overvoltage protective schemes, the generator voltage regulators are depended upon for overvoltage protection. However, as a matter of back-up protection, or where voltage regulators are not installed, facilities have been provided for tripping the field switch in case the generator voltage reaches an excessive value under runaway conditions. Where no main field switch is used, we have had success in using a small air circuit breaker to cut in resistance in the exciter field or to open the exciter field as a last resort. It also seems desirable to remove the excitation from the machine in case the differential protective equipment functions. A field switch in the exciter field seems to function satisfactorily in the absence of a main field switch.

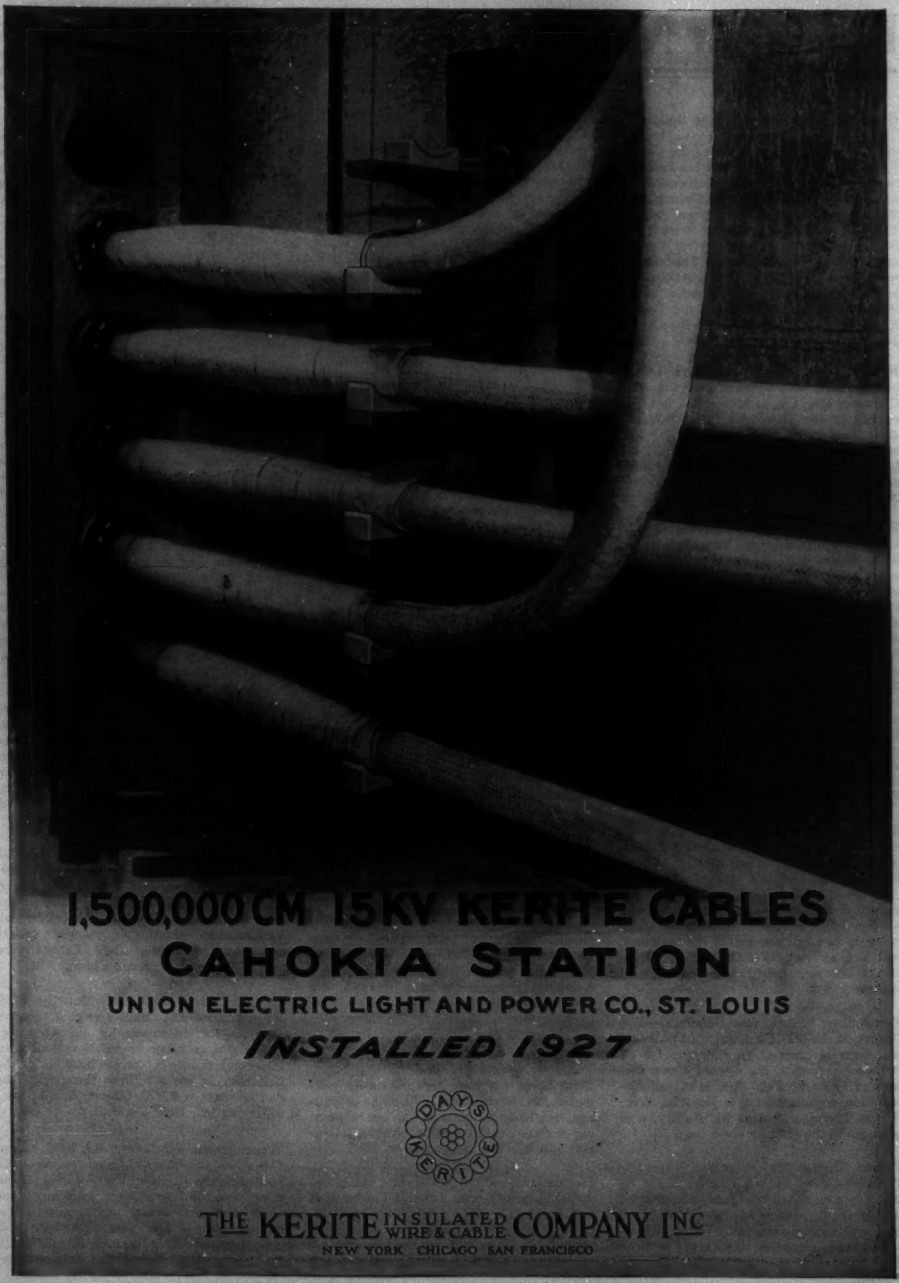
The necessity of providing special current transformers for high-speed differential relaying is a problem requiring further detailed investigation so that a better understanding may be had of the performance of current transformers during the early transient stages of a fault.

Governor Flyball Drive

The use of an electrical drive for the governor has been a very desirable development, but our experience indicates that serious trouble may be experienced if the drive receives its energy from slip rings on the pilot exciter, especially if the generator is equipped with a voltage regulator. Permanent-magnet generators provide a very satisfactory source of supply for governor motors.

Control Boards

Our experience with automatic synchronizing equipment indicates that while satisfactory performance can be obtained under steady-state conditions, certain types of equipment may fail to function during transient conditions or emergencies, and it is most needed at these latter times.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Industrial Notes

General Electric Plans Chicago Building.—The purchase of a large plot for the erection of a modern building to house the General Electric Company's Chicago headquarters, has been consummated. An expenditure of some $2,500,000 is involved, of which about 20 per cent represents investment in land. The site occupies the block bounded by South Canal, South Clinton, West Cabrini, and West Arthington Streets. The building, work on which will be started soon, will house the General Electric sales offices, warehouse, and service shop, the General Electric Supply Corporation, R. Cooper, Jr., Inc., and associated interests.

Newark Branch for Allis-Chalmers.—A new branch office and warehouse of the Allis-Chalmers Mfg. Co., of Milwaukee, has been opened in the Industrial Office Building, 1060 Broad Street, Newark, N. J. This office, of which C. A. Pihl is manager, will be a branch of the New York district office and will provide additional service in the Newark area for the company's products.

Roller-Smith Offices to Bethlehem.—The Roller-Smith Company has consolidated its executive offices (located prior to February 1 in New York City) with its works at Bethlehem, Pa., where all activities of the company are now concentrated. The district sales agencies in New York City and in all principal cities in the United States and Canada are not affected. Officers of the company are J. D. Wood, president and chief engineer; G. L. Crosby, vice-president and general sales manager, and W. J. Schuhmann, treasurer. Vice-President Crosby has announced the appointment of W. R. Swoish as sales manager, with headquarters at Bethlehem. He was formerly switchgear supervisor for Westinghouse, at Chicago.

Eastern Factory Office for Sterling.—To take care of an increasing amount of eastern territory business, Sterling Electric Motors, Inc., of Los Angeles, manufacturers of "Slo-speed" and "Speed-trol" motors has opened direct factory offices temporarily at 81 San Miguel Street, Springfield, Mass. Allen A. Adams, treasurer of the company, will act as eastern manager. Adequate stocks are now being carried at several eastern points.

Transformer Plant for Delaware.—The Robert M. Hadley Company, of Los Angeles, manufacturers of transformers for all radio requirements, has opened a new factory at Newark, Del. The sales and distribution organization is under the direction of President Robert M. Hadley, who has been in the East for some time.

Private Utilities Major Turbine Buyers.—Private utilities still account for about 88 per cent of all the turbine generators bought in this country, and most of them purchased during the past year were of the hydrogen-cooled type, according to a survey of large unit purchases made by W. E. Blowney, turbine engineer for the General Electric Company. His study was based on his company's sales of turbine generators rated 10,000 kilowatts and above, exclusive of those for marine propulsion, during the two four-year periods 1926–29 and 1935–38. The survey revealed that industries and municipalities bought a larger percentage of turbines in the 1935–38 period than they did in the years 1926 through 1929, but that their share represented only a small part of the total volume. Private utilities remained the big buyers and accounted for all but twelve per cent of the business.

Trade Literature

Diesel Machinery.—Catalog, 32 pp. Describes diesel tractors, graders, industrial engines and electric generator sets. Caterpillar Tractor Co., Peoria, Ill.

Portable Electric Tools.—Catalog, 60 pp. Describes drills and miscellaneous portable tools; prices are included. The Van Dorn Electric Tool Co., Towson, Md.

Motors.—Manual 21-121, 4 pp. Describes installation, care and adjustment of fractional horsepower, capacitor, single-phase motors. Century Electric Co., 1806 Pine St., St. Louis, Mo.

Motors.—Bulletin C-4. Describes heavy duty, d-c mill motors. Construction details are fully illustrated and outlined. Harnischfeger Corp., 4400 W. National Ave., Milwaukee, Wis.

Breather for Transformers.—Bulletin 2325, 4 pp. Describes operation and advantage of the new "Uni-Directional" breather used on power transformers and step type feeder voltage regulators. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Condensate-Purity Instruments.—Catalog N-95-163, 20 pp., "Micromax Condensate-Purity Instruments for the Steam Plant." Describes instruments and methods for continuously determining variations in condensate purity. Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia, Pa.

Voltmeter.—Bulletin GEA 3046, 2 pp. Describes a portable, high resistance voltmeter for approximate indications of voltage, particularly designed for use in phasing out power distribution circuits. General Electric Co., Schenectady, N. Y.

Instruments.—Cat. 48-A, 8 pp. Describes a complete line of 3- and 4-inch round and square a-c and d-c ammeters, milliammeters and microammeters, voltmeters, single- and polyphase wattmeters and pyrometers. Included is a new group of 4-inch square instruments, available in both surface and flush models, which form a companion line to the 3-inch square instruments recently announced. The 3- and 4-inch round instruments have been on the market for many years. Roller-Smith Co., 12 Park Pl., New York City.

Motors.—Bulletin 3530, 4 pp. Describes hoist and crane motors, with intermittent ratings of from 1 to 200 horsepower, and designed for operation at commercial frequencies and voltages. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Fluorescent Lamp Control.—Cat. Sec. 61-275, 2 pp. Describes control units used with tubular fluorescent lamps to maintain voltage at proper values; for use on 60-cycle service. The over-all power factor for lamps and control is approximately 60 per cent. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Insulating Compound.—Bulletin. Describes a new type of ozone- and moisture-resisting insulating compound, "Uskorona." The compound is applicable to splicing underground conductors and on overhead power lines. United States Rubber Co., Mech. Goods Div., 1790 Broadway, New York City.

Motors.—Bulletin 508E. Describes a complete new line of a-c and d-c explosion-proof motors. According to the manufacturer, 18 separate and distinct major mechanical and electrical improvements, several of which are exclusive patented features, are incorporated in the new products described in the bulletin. The Louis Allis Co., Milwaukee, Wis.

Mining Cable.—Bulletin, 4 pp. Describes "Sunex Securityflex," a new mining cable covering for all types of cords and cables. Sun, heat, moisture, alkali and acid resistant, the new insulation combines flexibility with extreme toughness and high resistance to abrasion. Anaconda Wire & Cable Co., 25 Broadway, New York City.

Instruments.—"G-M Comments," No. 10, 8 pp. Includes description of a new supersensitive photoelectric foot-candle meter, and a new series of self-generating photoelectric cells. Additional data covers galvanometers, phototubes, power supply units and rheostats. G-M Laboratories, Inc., 1733 Belmont Ave., Chicago, Ill.

Signal Control Switches.—Bulletin SCS, 2 pp. Describes Sauter signal control switches for automatically closing a signal, alarm or other circuit, for from 2 to 25 seconds duration, "on the hour" or on the half hour at various times throughout the day or night. R. W. Cramer & Co., Inc., 67 Irving Pl., New York City.

Transformers.—Bulletin GEA 3085, 12 pp Describes "Spirakore" single phase, oil-immersed distribution transformers, using a new wound-core design, enabling lower costs and improving performance. The development of the wound-core principle is elaborated in Bulletin GES 2038, 28 pp. General Electric Co., Schenectady.

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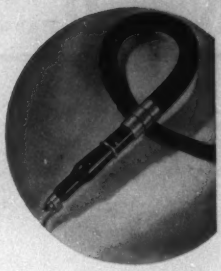

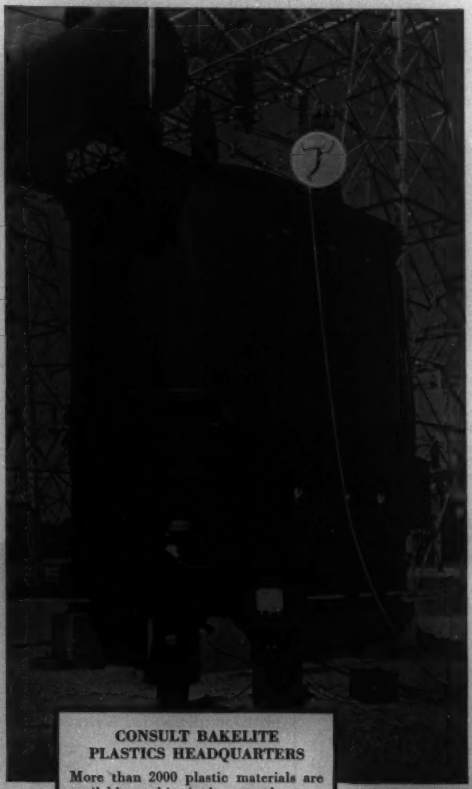

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New Products

Cable Fault Indicator.—Power cable faults can be located in minimum time with a new modification of the Murray Loop Circuit, made by the Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia, Pa. Developed

jointly by T. B. Morse of the Commonwealth Edison Co., and C. W. Newhall, Jr., of the Public Service Co. of Northern Illinois, it has been used by these two companies with marked success, according to the manufacturer. Operating at very high voltages, it eliminates the necessity for breaking down fault resistances. A long spiral slide-wire assures high accuracy so that faults are usually located after a single measurement. Easily portable, one equipment can cover a wide territory. In addition to its use for Murray loop tests, the Morse-Newhall test assembly is adapted for Wheatstone bridge measurements and for approximations of resistances by the voltmeter method. These auxiliary circuits make it possible to analyze faults on the same instrument used to locate them.

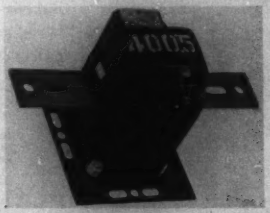
Speed Controller for A-C Motors.—The Raytheon Mfg. Co., Waltham, Mass., has developed a multi-step speed controller for a-c motors which makes it possible to vary the motor speed by changing the input voltage. This method of control permits operation by a thermostat or automatic

switch, because it insures that the motor will always re-start, regardless of the controller setting. A typical controller is illustrated, showing its principal components, an autotransformer with voltage adjustment taps and an oil-filled condenser. There are no moving parts. Controllers are adapted for wall mounting; within a ventilated cabinet; or on the motor itself. Any desired method of voltage control can be furnished, for example, a movable link as shown, or an enclosed multi-position tap switch.

Bus Support.—Improvements in the design of bus support type UH, a product of the Burndy Engineering Co., Inc., 459 East 133rd St., New York City, include the following features: interlocking teeth have been provided on the neck of the device, permitting the tubular bus to be set

at an angle to the steel structure; finer adjustments than are obtainable through the use of the interlocking teeth may be made by means of the slightly ovalized bolt holes in the base; also, the tube clamping members are so arranged that either a tight fit or a slide fit may be obtained.

Indoor Current Transformer.—A new indoor current transformer, designed to combine the advantages of small size with high



accuracy for metering on low voltage circuits, has been introduced by the General Electric Co. Designated type JL-1, it is rated 600 volts and is offered in three current ratings: 200/5; 400/5 and 600/5 amperes. Primary windings are of sufficient size to permit continuous operation at 150 per cent of rated primary current. Primary terminal surfaces are silver-plated, and the secondary terminals are of the solderless type, easily operated with a screw driver. A removable mounting plate permits placing the transformer on pipe.

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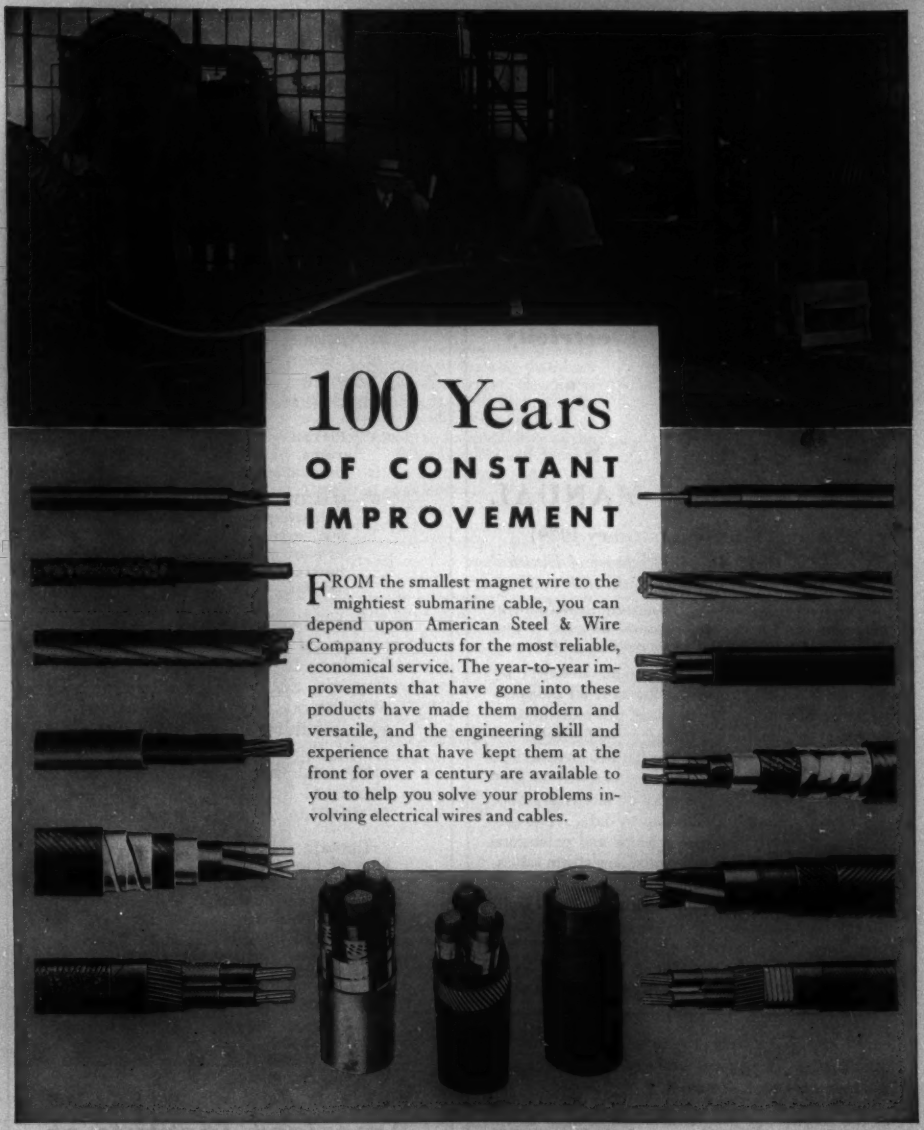

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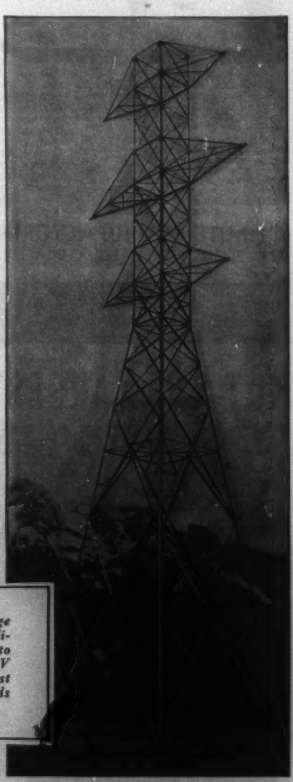

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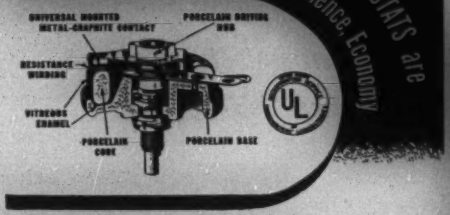

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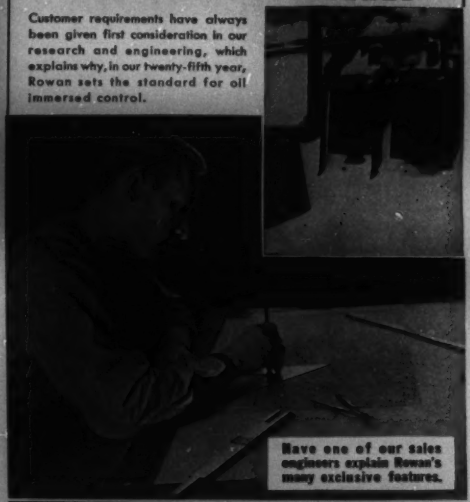

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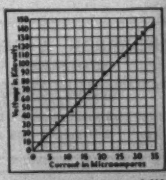

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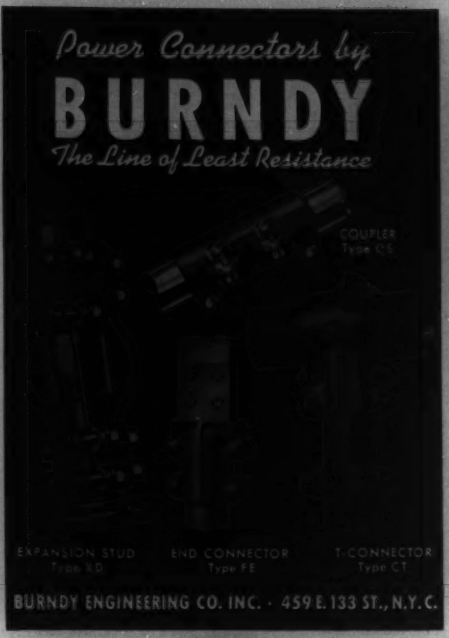
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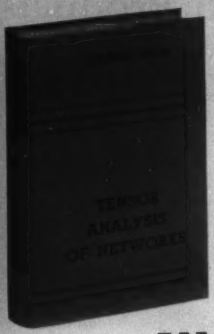

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Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
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American Steel & Wire Co., Chicago
Anaconda Wire & Cable Co., New York
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General Cable Corp., New York
Kerite Ins. Wire & Cable Co., New York
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Weatherproof
American Steel & Wire Co., Chicago
Anaconda Wire & Cable Co., New York
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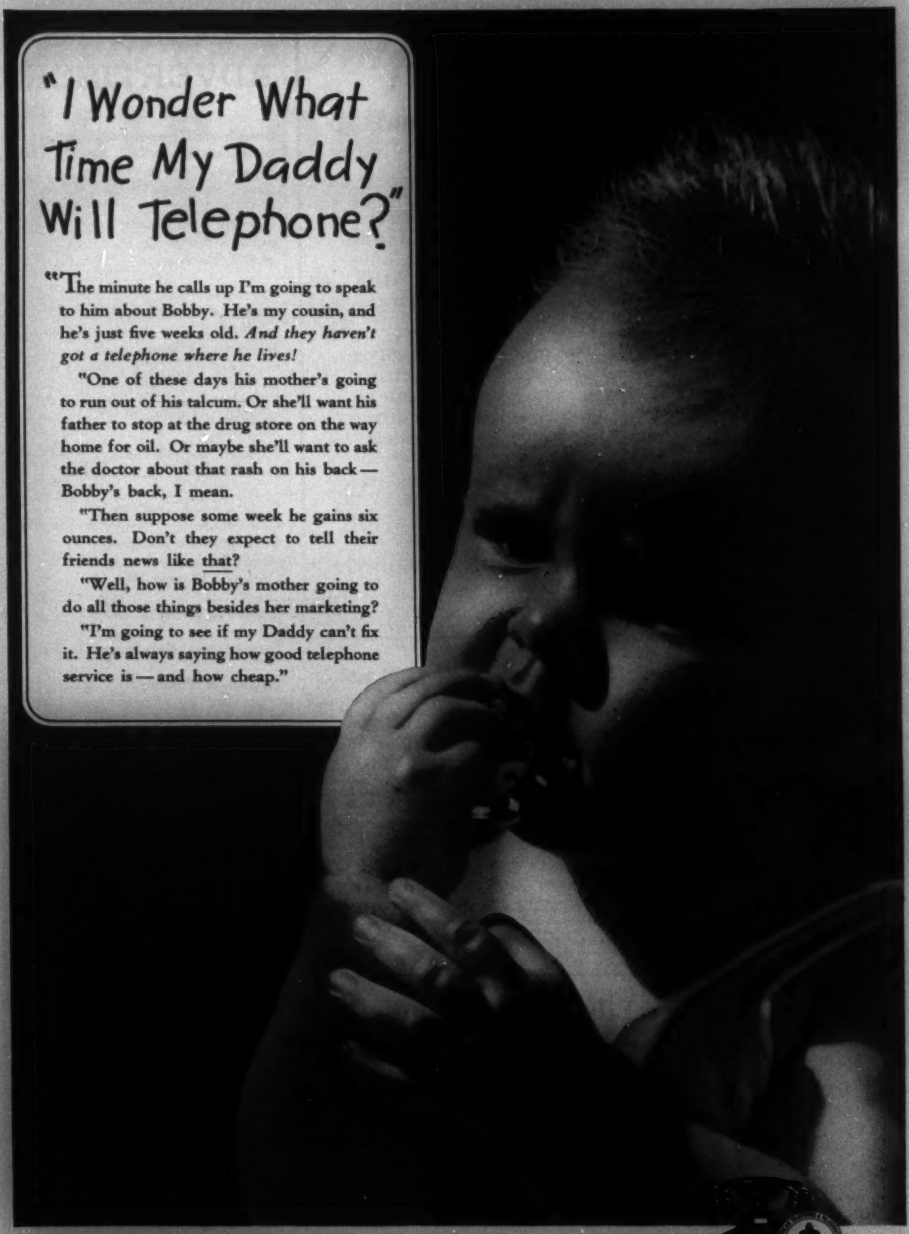
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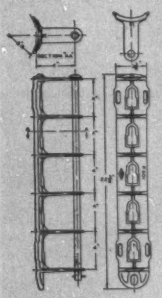

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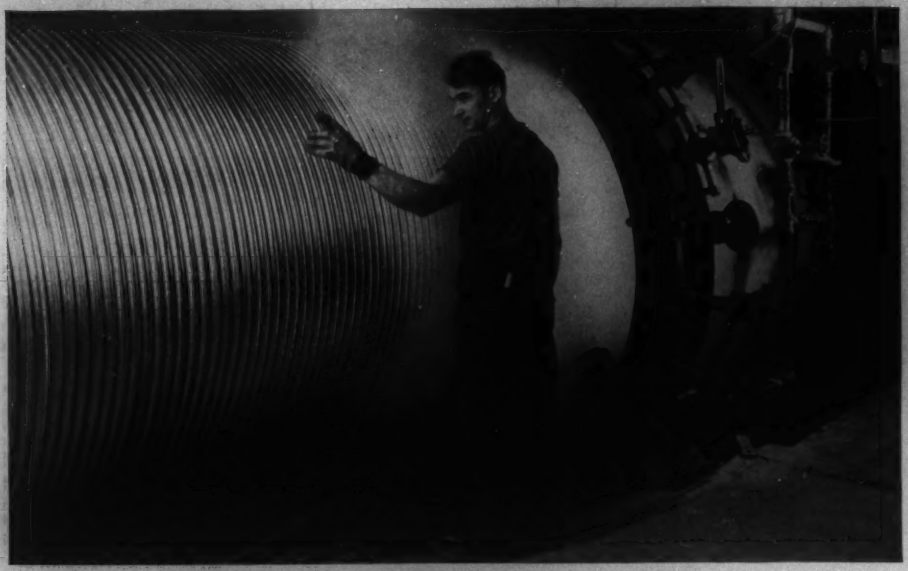

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